Passenger Counting and Service Monitoring

A Worldwide Survey of Transportation Agency Practices

New York City Transit

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PREFACE

This report, issued by MTA New York City Transit's (NYC Transit) Division of Operations Planning, covers research conducted in the years 2001 through 2003.

In August 2001, NYC Transit surveyed metros from around the world under the auspices of CoMET, the Committee of Major Metros. CoMET provides a forum for the nine participating large international transit agencies (Berlin, Hong Kong, London, Mexico City, Moscow, New York, Paris, São Paulo, and Tokyo) to share information and compare practices. This questionnaire was based on the CoMET goal of gathering and sharing information on peer practices and experiences.

Rachel M. Healy and Ross A. Kapilian supervised and provided assistance to intern Madeleine R. Masters in writing this report. Ms. Healy and interns Adam D. Torres and Robert L. Fraley also contributed research and writing. We wish to thank our colleagues throughout the world, whose generous participation in the survey made this research possible.

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PASSENGER COUNTING AND SERVICE MONITORING:

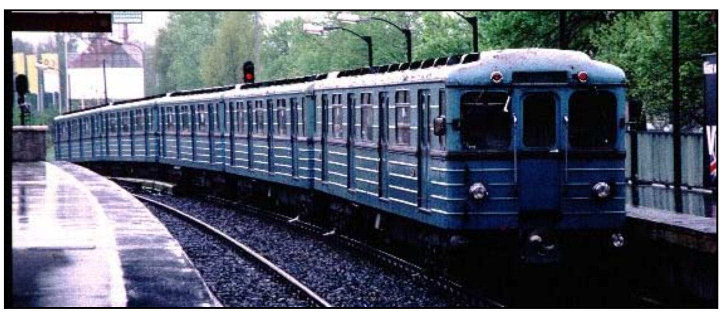
A Worldwide Study of Transportation Agency Practices

New York City Transit

Strategic use of information is essential to the provision of quality transit service. New technologies are supplementing traditional methods of data acquisition and processing, providing transit agencies with more accurate and comprehensive information. This paper examines the state of the practice of methods and technologies for data collection and use in passenger counting and service monitoring.

Introduction

In August 2001, MTA New York City (New York City Transit) surveyed metros from around the world about methods and technologies used for counting passengers and monitoring service. These issues reflect areas of recent technological development that are of interest to New York City Transit and other agencies.



In examining these topics, New York City Transit intended to increase its knowledge base, and had three broad objectives:

- Focus on practices as a means to illustrate how transit agencies throughout the world address basic operational issues.
- Promote sharing of information on an international basis.
- Compare international practices addressing similar topics.

Topics Addressed

The topics covered in the survey were chosen because they are essential to helping transit agencies plan and evaluate the quality of service provision, by tracking both the demand and supply of transit service.

Passenger counting allows transit providers to determine how many passengers are using each mode of transit, at different locations and different times of day. Identifying significant passenger load points helps indicate where service is excessive or deficient, assisting service planning and schedule adjustment. Technologies supplementing or replacing manual passenger counts include ticket-based counting and a spectrum of technologies known as APC (automatic passenger counting) devices. Some specific benefits of passenger counting technologies are:

- Collection of disaggregate data at lower cost and with greater accuracy than manual counting (especially with APC devices), and the ability to aggregate data as needed.
- Closer, more accurate relation of passenger boardings and alightings with respective locations.
- With infrared technologies, increased capacity to understand passenger flow on individual trains.

Service monitoring technology provides information about system operations and schedule adherence, assisting transit agencies in enhancing service provision. By tracking vehicle reliability and punctuality, this technology illustrates the quality and adequacy of service. Through analysis of service trends, agencies may address a number of issues (e.g., operational, infrastructure-related) that affect service. Service monitoring technologies include track or route-based monitoring systems, automatic train supervision (ATS), and automatic vehicle location (AVL). These technologies collect various types of information necessary to improving service, including:

- On-time performance (OTP) information, including arrival and departure times.
- Vehicle location, in delay or real time.
- Vehicle and platform load information.
- Statistics on delays, breakdowns, accidents, and their causes.

Survey responses indicated that, in general, passenger counting and service monitoring technologies offer the following benefits over traditional manual methods:

- Increased levels of data accuracy, through larger samples and more accurate data collection.
- Greater frequency of data collection.
- Ability to collect data at disaggregate, as well as aggregate, levels—even operator-level data.
- Potential for technology to automatically process data.

In response to security concerns, New York City Transit has elected not to publish a third chapter of this report, which was to have examined security monitoring technologies.

Research Efforts

In August 2001, New York City Transit surveyed over 50 metros, commuter railroads, and surface transport providers around the world to evaluate technological change in passenger counting and service monitoring. New York City Transit also conducted a literature search on issues related to these topics. The findings from the surveys and the literature review are included in each section of the report.

As shown in Table I-1, 31 agencies, primarily metros and commuter rail agencies from six continents, responded to the questionnaire. Of these, 24 reported on passenger counting and 29 reported on service monitoring. To provide context for the study findings, a brief profile of each agency is provided in Appendix A and more detailed subject summaries are provided in each chapter. The size of the agencies responding to the surveys varied. Some agencies gave combined responses for all modes, while others reported on different modes individually. Annual ridership ranged from 14.5 million in Glasgow to 1.4 billion in Mexico City and New York City metros.

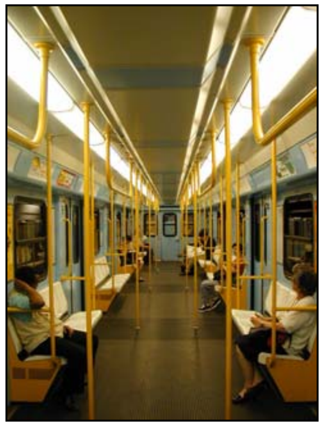


Table I-1
Questionnaire Respondents

City	Service Provided
Berlin, Germany	Metro, Bus, Tram
Hong Kong (MTR)	Metro
Mexico City, Mexico	Metro
New York City, USA (Bus)	Bus
New York City, USA (Subway)	Metro
São Paulo, Brazil	Metro
Tokyo, Japan	Metro
Athens, Greece (Attiko)	Metro
Athens, Greece (OASA)	Metro, Bus, Trolley
Barcelona, Spain	Metro, Bus
Boston, USA	Metro, Bus, Trolley, Tram, Suburban Rail
Budapest, Hungary (Bus)	Bus
Budapest, Hungary (Metro)	Metro
Glasgow, Scotland	Metro
Hamburg, Germany	Metro, Bus
Jersey City, USA (PATH)	Metro
Los Angeles, USA	Metro, Light Rail, Bus
Miami, USA	Metro, Bus, Automated Guideway
Milan, Italy	Metro, Bus, Tram, Trolley
Montreal, Canada	Metro, Bus
Portland, USA	Bus, Light Rail
Prague, Czech Republic	Metro, Bus, Tram
Rio de Janeiro, Brazil	Metro
San Francisco, USA (BART)	Metro
Singapore	Metro, Light Rail
South Africa	Commuter Rail
Stockholm, Sweden	Metro, Light Rail, Commuter Rail, Bus
Sydney, Australia	Commuter Rail
Taipei, Taiwan	Metro
Toronto, Canada (Subway)	Metro
Toronto, Canada (Surface)	Bus, Streetcar

Summary of Findings

The following is an overview of survey findings. Detailed findings are presented in Part One, "Passenger Counting Technology" and Part Two, "Service Monitoring Technology." Individual agency responses to the surveys are provided in Appendices B and C.

Passenger Counting Technology

Although the practice of passenger counting is still dominated by manual methods, agencies are increasingly taking advantage of the benefits offered by passenger counting technologies. Traditional methods of counting include conducting manual staff counts and counting ticketed entries, while automatic passenger counting features an array of emerging technologies, such as infrared and weighing devices. Technology-based counting methods offer increased accuracy of data, reduction of costs associated with manual counting, and the potential to automatically integrate data with other data collection systems. In short, passenger counting technology increases the scope and quality of ridership data available to transit planners.

Passenger Counting Methods

- Technologies: After manual counts, the most common technologies used to count passengers are ticket counting devices (e.g., electronic fareboxes and turnstiles) and doorway infrared counting. Other technologies used are treadle mats, pneumatic vehicle weighing devices, photovoltaic cells, and thermal devices.

- Data Sought: Agencies count passengers on vehicles, entering and exiting stations, entering and exiting vehicles, and transferring between routes or lines. Data are used primarily to understand ridership numbers and patterns (16 agencies), but they are also used for analysis of on-time performance issues (seven agencies), revenue issues (three agencies), and other issues (nine agencies). In general, data are 95% accurate or better; data from automatic fare collection devices (AFCs) are reported to be 99% to 100% accurate.

- Coverage: System coverage by counting technologies ranges from 2.6% (in Hamburg) to 100% in several agencies. Agencies report that full system coverage is not necessary to achieve good results. Six of the seven agencies with 100% coverage use ticket counting devices (e.g., turnstiles and electronic fareboxes), and the seventh agency (Prague) has full coverage by infrared detection at station gates.

- Use of Data: In most responding agencies, passenger counting is an independent operation, but six agencies integrate passenger counting technology with AVL, and eight agencies integrate it with other data systems, e.g., ATS (automatic train supervision), AVMS (automatic vehicle maintenance systems), and passenger announcements.

  Data are used to produce ridership reports; they may also be used for analyses of revenue, on-time performance, and other issues. Ridership data are primarily used to identify needed service adjustments. Half of respondents also use data for origin/destination analysis. Nearly all responding agencies have found that passenger counting technology has helped them improve service provision.

Manual Counting Methods
Manual methods still dominate the practice of passenger counting, with 19 responding agencies using manual techniques (platform counts by staff and passenger surveys). Manual counting is a flexible counting method, making it useful for counting passengers in all modes of travel, whether entering and exiting vehicles and stations, on-board vehicles, or transferring between routes or lines. However, it is labor-intensive and subject to error. Passenger counting technology is making gains on manual techniques, serving to reduce the intensive use of human resources, confirm accuracy of data, increase the scope of data collection, and in a few agencies, replace manual techniques altogether.

Counting from Ticketed Entries
Thirteen agencies estimate ridership from ticketed entries. This includes using electronic registering fareboxes (ERFs) and automatic fare collection devices (AFCs), such as automatic turnstiles and smart cards. ERFs are more commonly used on buses, while ticket gates and turnstiles are used in metro stations.

Ticketed entries are best suited to providing aggregate (e.g., route-wide or systemwide) data.[1] For example, among respondents, counting from ticketed entries is the most common method of determining station entries (even more than manual methods). This method is also used to count passengers in other stages of travel. Other counting methods may be required to determine disaggregate data (e.g., time of day data, stop data for buses, and route/line data for rail passengers), although most agencies with ticket-based systems report collecting disaggregate data with their technology.

Automatic Passenger Counting
Ten agencies have automatic passenger counting (APC) systems. The most common form of APC technology is doorway infrared detection, used in four agencies (Berlin, Hamburg, Los Angeles, Portland). Other forms of APC include infrared detection at station gates (Milan, Prague), treadle mats (Montreal), pneumatic weighing devices (Budapest), photovoltaic cells (Milan, Stockholm), and thermal devices (Athens OASA).

APCs are well suited to collecting data on disaggregate levels, for both bus and rail applications.[2] APCs are most commonly used among respondents for counting vehicle entries and exits; pneumatic weighing estimates the number of on-board passengers.

Service Monitoring Technology

Monitoring service provision helps agencies determine which routes need service adjustments and identify service problems. While manual methods are still

[1] Transit Cooperative Research Program (TCRP), Synthesis 29, 1998. "Passenger Counting Technologies and Procedures," p. 12.

[2] TCRP 29, p. 13.

widely used to monitor service, there has been a recent trend of taking advantage of emerging technologies. These offer many different combinations of data collection, while increasing data accuracy and supplementing (or reducing the need for) manual monitoring.

Service Monitoring Methods/Trends

- Technologies: For years agencies have monitored service with staff (separate monitoring staff and dispatchers) and with track/route-based monitoring technologies. Service may also be monitored with cameras. However, two technologies are eclipsing other methods of determining the reliability and punctuality of trains and buses: Automatic Train Supervision (ATS) and Automatic Vehicle Location (AVL). ATS monitors train service, whereas AVL can be used on trains and buses. ATS and AVL may be designed in many different ways, with varying capabilities.

- Functions of Technology: Agencies indicate that service monitoring technology (of all types) is primarily used to determine on-time performance (OTP) of vehicles. Service monitoring may also provide continuous time-space information for vehicles, vehicle loads, equipment status, and, in the case of some ATS applications, automatic train operation. Equipment is sometimes integrated with other data collection systems; in particular, AVL is often used with passenger counting technology.

- Coverage: The range of vehicle coverage by service monitoring technologies (all types) is between 60% and 100%, with a median of 100%. ATS, AVL, and route/track based monitoring have especially high levels of vehicle coverage, (on average, 97%, 83%, and 95%, respectively). Camera monitoring is less common on vehicles, but covers 100% of stations/stops in the four responding agencies that reported monitoring service with cameras.

- Use of Data: Data are used to adjust schedules and service, as well as to identify sources of problems and delays. These changes result in improved service and potentially significant cost savings. Most agencies gather data continually, by line. Data are commonly disseminated via intranet or through a central group (e.g., planning, analysis, control center), although they may also be disseminated manually, on display boards, or through other technology. Agencies generally find data to be accurate; agencies typically use manual means of verification, although some agencies' computers verify data.

Manual Methods

Most agencies use some form of manual monitoring to study service provision; 12 agencies use dispatchers, and 11 agencies use separate monitoring staff. Staff provide much of the same categories of information as service monitoring technologies (though not as continuously). Manual collection is resource-intensive, and is increasingly being supplemented with — and replaced by — newer technologies.

Automatic Train Supervision (ATS)

Fifteen agencies use ATS. This is used almost exclusively to provide various performance indicators, such as arrival and departure times, deviations, trip duration, and station dwell times. In Miami ATS also provides continuous time-space information, while in Singapore ATS also performs AVL and dispatching functions. In 11 agencies using ATS, 100% of vehicles are monitored; Miami monitors a random sample of vehicles. Six agencies are considering implementing ATS; three of these are considering Automatic Train Operation (a type of ATS).

Automatic Vehicle Location (AVL)
Seventeen agencies use AVL. Predictably, this technology is used to provide vehicle location, which is used to measure performance (using similar indicators as for ATS). AVL also provides vehicles identification, loads, and headways. AVL systems may be integrated with passenger counting technology and with customer service announcements. Seven agencies are considering implementing (or expanding current use of) AVL, three of these considering GPS.

Other Monitoring Systems
Less common methods of service monitoring are track and route-based systems, used in five agencies, and camera monitoring, used in four agencies.

Caveat
The ability of technologies to provide large quantities of data can be problematic, just as it can be extremely beneficial when used properly. For example, Portland has used complex data analysis to plan more efficient service, but Athens Attiko reports being unable to process all their data as required for daily analysis. While collection costs may decrease with technology implementation, the costs of analysis and storage may rise. These are important considerations, since raw data must be transformed into analyses and applications to be useful to agencies.

Summary

Agencies are increasingly taking advantage of the many benefits of new technologies for passenger counting and service monitoring, as they expand and upgrade these programs. Overall, agencies view technology as an effective supplement to manual techniques, for improving service and increasing customer satisfaction.

PART ONE:

PASSENGER COUNTING TECHNOLOGY

Introduction

Transit agency analysis of ridership patterns is an essential element in providing effective and efficient transit service. A variety of techniques and technologies can be employed to collect, sort, tabulate, and evaluate data to best fit agencies' individual service objectives. The purpose of this survey is to look at how agencies are using technology to collect data on ridership levels and how data are then used to allocate service.

Passenger counting determines the number of passengers using transit at a given time and place, by counting passengers boarding and alighting at a station or stop during a specific time period. Manual counting methods are still prevalent, but it is becoming more common to estimate ridership from ticketed entries and/or to count with automatic passenger counting devices (APCs). Each of these data collection methods has different methodological and technical applications, which are reviewed in this chapter.

Passenger counts are most useful for analysis when they are closely linked to both location and time. This requirement has different implications for counting passengers on trains and on buses. For rail passengers, it is more common to track station entries and exits than vehicle entries and exits; agencies must then determine what routes, lines, and/or cars rail passengers use after entering stations. By contrast, bus passengers are typically counted as they enter and/or exit vehicles, not as they approach or depart from stops, so it is necessary to correlate passenger entries with boarding locations and exits with alighting locations.

Overview of Topics Covered

Agencies use an assortment of passenger counting technologies to inform their operations. This survey addressed the following topics regarding agencies' use of passenger counting technology:

- Categories of passenger counts (e.g., passengers on-board vehicles, entering stations, exiting stations, entering vehicles, exiting vehicles) and counting frequency.
- Technologies used for counting passengers, including type, manufacturer, date of manufacture, unit mobility, and functions.
- Coverage of vehicles/stations by each technology.
- Integration of passenger counting with other data collection systems.
- Data provided, accuracy of data, and methods of data verification.
- Use of data, including storage, reports produced from data, and problems identified with technology.
- Plans to expand or upgrade current systems.
- Evaluation of whether and how technology has helped to improve service provision.

Types of Passenger Counting Technology and Their Capabilities

There is no best technique or technology for counting passengers, but rather a spectrum of options, each suited to different counting purposes.[1] Certain techniques are more suitable for collecting aggregate (e.g., route-level or systemwide) data, while others are more appropriate for disaggregate (e.g., time period, stop/station-level) data. Likewise, different levels of data collection are useful for different analytical purposes. Generally, aggregate data is valuable to agency heads or funding institutions, who look at systemwide success and trends on month-to-month or annual bases, and disaggregate data are valuable to schedulers and service planners, who use more specific data to adjust existing service plans.[2]

Manual Counts

The most common way of counting passengers is manually. Manual staff counts are well suited to collecting disaggregate data. On buses, staff may record passenger numbers and boarding/alighting locations. For rail passengers, it can be difficult to determine specific car entries, exits, and passenger loads; instead, staff usually estimate loads and infer route/line ridership by correlating station entries/exits with train arrivals/departures. Because manual passenger counting is difficult, resource-intensive, and subject to non-random error, it is often replaced by or used in conjunction with one or more passenger counting technologies.[3]

Ticketed Entries

Agencies may also count passengers from ticketed entries into the system. This includes use of Automatic Fare Collection devices (AFCs) and electronic registering fareboxes. This method is best suited to providing data on route or systemwide (aggregate) levels. Data are usually verified by comparing ticket counts to revenue data or manual counts.[4]

Electronic registering fareboxes (ERFs) may be used to count passengers on buses; bus operators may need to enter trip codes, or the technology may use GPS or mileage counts to determine location.

For rail passengers, AFC devices such as turnstiles or faregates may be used. These record passenger entries and/or exits, and often entry/exit times at each station. Smart Cards are an example of AFC devices useful for passenger counting that may be used for rail or bus passengers. Some agencies use AFC equipment to analyze origin/destination trends. Some agencies, such as Washington, D.C. Metro, San Francisco (BART), and Sydney, have exit turnstiles that take tickets and can determine origin/destination statistics automatically. New York City Subways counts passengers entering stations, and has a computer model that infers destinations from origin swipes, comparing morning and afternoon swipes. Origin/destination tables are generated from this model and used to analyze line ridership and passenger flows.

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[1] Transit Cooperative Research Program (TCRP), Synthesis 29, 1998. "Passenger Counting Technologies and Procedures," p. 3.
[2] Ibid, p. 7.
[3] Ibid, p. 11-12.
[4] Ibid, p. 12.

Automatic passenger counting devices (APCs)

APC systems include infrared counting devices, treadle mats, thermal counting devices, photovoltaic cells, and vehicle weighing devices. These systems are considered appropriate for collecting disaggregate data.

APCs are commonly used to count bus passengers, using GPS, signposts (radio frequency or optical), or dead reckoning equipment to relate passenger entries/exits to locations.[5]

In general, using APCs to count passengers on trains may be more difficult than for counting passengers on buses, due to complications unique to railcar entry (e.g., more erratic passenger movement, wide and/or multiple loading points). However, some agencies, including Berlin and Hamburg, are using APCs successfully in their trains.

Infrared detection is the most common APC technology. This technology works by registering interruptions of an infrared beam; each interruption represents a passenger boarding/alighting. Through a combination of hardware and software, infrared APC systems can determine in which direction a passenger is moving (boarding or alighting) and how many passengers are moving in the beam's path.[6] On-board computers can combine APC data with AVL data and other information, as fit for agency needs. Indicators include time, vehicle ID, block ID, bus stop ID, vehicle position count, route, direction, destination, and service indicators.[7] Infrared devices can either be mounted in doorways, to count entries and exits, or they may span entire vehicle interiors to get on-board passenger loads.

Other types of APC include "contact" APC and vehicle weighing. "Contact APC," such as treadle mats, switch matrices, and smart mats, relies on physical contact to count passengers, using embedded switches that recognize passenger entries and exits. Smart mats contain optical fibers that sense deflection and register foot placement.[8] Budapest's vehicle weighing system is described in the *Findings: Summary of Responses* section of this chapter.

Unless agencies require information on real-time loads for an entire system, APCs need not be purchased for 100% of vehicles; equipping 10% of the fleet is adequate for most agencies' data needs.[9] Different levels of implementation of APCs throughout the system can provide valuable data to agencies.

Implementation of Technology

The development of appropriate business applications is key to successful passenger counting data collection and analysis. Careful oversight, staff training, and quality assurance must accompany the implementation of data collection technology. Technology — while extremely valuable — will not bring an end to all inaccuracies and inconveniences. Agencies can expect some mechanical, software, and personnel-related problems to occur with technology, especially during initial "breaking-in" or "de-bugging" periods.[10]

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5 More information on this is available at www.permetricstech.com/tutorial1.html.
6 www.mta.net/other_info/ATMS/APC_technology.htm (LACMTA website)
7 www.tms-online.com/products_transit_smartcount.html (SmartCount website).
8 www.permetricstech.com/tutorial1.html.
9 Ibid.
10 TCRP 29, p. 2-3.

Verification of data is another key element to program success. Accuracy of data involves determining statistical reliability, and can range from 85% to better than 95%, depending on variables such as type of technology, location of equipment, load types, and passenger behavior. The more common methods of data verification are comparing data from technology with revenue or manual data. Subsequent video analysis is also a reliable way to measure data accuracy.[11]

The Transit Cooperative Research Program (TCRP) cautions against commissioning unnecessarily customized systems, which are typically unsuccessful as well as costly. Collecting and processing more data than is truly needed may result in increased cost (of equipment and personnel) and "data gluts."[12] TCRP further emphasizes the importance of learning from other agencies' experiences before selecting a particular technology. No technology is perfect, but through appropriate combinations of available technologies, and careful use of human resources, transit planners can achieve successful results with passenger counting technology.[13]

Research Efforts

In August of 2001, NYC Transit surveyed agencies around the world to evaluate their use of five types of counting technology:

- Carwide infrared detection
- Automated fare sales and collection devices
- Infrared doorway counting devices
- Treadle mats
- Camera surveillance

The survey also inquired about manual methods and other technologies agencies used for counting passengers. Agencies were asked about the stages of travel that they counted (e.g., passengers entering vehicles, exiting vehicles, aboard vehicles, in stations) and the types of analyses for which these data were used. As shown in the following table, 25 agencies responded to the survey.

New York City Transit also researched issues related to passenger counting technology, consulting materials published by the Transit Cooperative Research Program, related websites, and technology manufacturers.

[11] www.permetricstech.com/tutorial1.html.
[12] Ibid.
[13] TCRP 29, p. 3.

Table II-1 Questionnaire Respondents	
City	**Service Described**
Berlin, Germany	Metro
Hong Kong (MTR)	Metro
Mexico City, Mexico	Metro
New York City, USA (Bus)	Bus
New York City, USA (Subway)	Metro
São Paulo, Brazil	Metro
Athens, Greece (Attiko)	Metro
Athens, Greece (OASA)	Metro, Bus, Trolley
Boston, USA	Metro, Bus
Budapest, Hungary (Bus)	Bus
Budapest, Hungary (Metro)	Metro
Glasgow, Scotland	Metro
Hamburg, Germany	Metro
Los Angeles, USA	Metro, Bus, Light Rail
Miami, USA	Metro, Bus, Automated Guideway
Milan, Italy	Metro, Bus, Tram, Trolley
Montreal, Canada	Bus
Portland, USA	Bus
Prague, Czech Republic	Metro, Bus
Rio de Janeiro, Brazil	Metro
San Francisco, USA (BART)	Metro
Stockholm, Sweden	Metro, Bus, Light Rail, Commuter Rail
Sydney, Australia	Commuter Rail
Taipei, Taiwan	Metro
Toronto, Canada	Metro, Bus

The objective of this research effort has been to highlight key aspects of passenger counting technology systems such as manual counting, ticket-based estimates, and automatic passenger counting devices, and their use in planning service and scheduling. These issues are of particular importance to New York City Transit as it considers the next generation of its passenger counting systems.

Findings: Summary of Responses

Passenger Counting Categories

Agencies use technology to count passengers in various stages of travel. Of the 25 agencies responding,

- 21 count passengers on vehicles
- 17 count passengers entering vehicles
- 17 count passengers exiting vehicles
- 17 count passengers transferring between routes or lines
- 21 count passengers entering stations
- 19 count passengers leaving stations.

Methods of Counting

Most responding agencies use a combination of counting methods to meet their needs — often using more than one method for a single purpose. Agencies conduct manual staff counts and surveys; estimate ridership from ticketed vehicle or station entries; and use automatic passenger counting (APC) systems. No agencies report using carwide infrared technology or cameras to count passengers.

Manual Methods

In spite of technological developments, manual methods are still prevalent for passenger counting. Nineteen of 25 responding agencies use manual methods for passenger counting. Manual methods include staff conducting manual counts and surveying passengers. Three agencies (Boston, Budapest Metro, and Toronto) exclusively use manual methods to count passengers.

Manual counts are used more than any other method to count passengers entering and exiting vehicles (12 of 20 agencies), exiting stations (11 of 20 agencies), transferring between lines (13 of 16 agencies), and on vehicles (15 of 19 agencies).

Surveying/interviewing customers is another manual method of determining origins and destinations or transfer patterns between routes or lines. Mexico City, New York City Bus (NYC Bus), New York City Subway (NYC Subway), Prague, Rio de Janeiro, and São Paulo conduct passenger surveys for ridership or transfer patterns.

Ticketed Entries

Calculating ridership from ticketed entries is more commonly used to count passengers entering stations (12 out of 22 respondents) than manual counts. Among technologies, counting from ticketed entries is the most common method for passengers entering vehicles (four of 20 agencies) and transferring between routes or lines (five of 16 agencies).

Ticketed entries are used to count passengers on vehicles by four of 19 agencies, passengers transferring between lines by five of 16 agencies, and passengers exiting stations by nine of 20 agencies.

Four responding agencies have full coverage by ticket-based technology: Rio de Janeiro has AFC gates in all stations; New York City has MetroCard fareboxes on all buses and MetroCard turnstiles in all stations; and all of Mexico City's stations are equipped with automatic turnstiles. Agencies' equipment ranges in year of manufacture from 1980 to 1990. Several manufacturers provide equipment; Cubic is used by seven agencies.

Automatic Passenger Counting

Automatic Passenger Counting devices (APCs) are an increasingly common technology for counting passengers, because of their flexibility and ability to collect and process data. APC technology includes infrared counting devices, treadle mats, and vehicle weighing devices.

Among responding agencies, infrared detection is the most common technology for counting passengers entering vehicles and passengers exiting vehicles, with five of 20 responding agencies. Three agencies use it to count passengers on-board vehicles, and one agency (Prague) uses it to count passengers entering and exiting stations.

Milan and Prague have infrared counting devices at turnstiles and entry gates. Milan counts passengers entering and exiting vehicles, and Prague counts passengers entering and exiting stations. Los Angeles and Portland use doorway infrared detection to count passengers on-board, entering, and exiting buses.

Berlin and Hamburg use doorway infrared devices to count passengers boarding and alighting rail cars, which has previously been considered a complex task. Six percent of Berlin's railcars have infrared sensors in their doorways. These sensors count passengers, determining whether they are entering or exiting the car (even in complex passenger movements).[14] Counts are recorded for each stop at door-level or vehicle-level, and information is sent to a processing unit in the lead car.[15] This information is uploaded to a computer at the terminal station, which relays to headquarters in one to two days. Data transfer (in vehicles and at terminals) may be accomplished by radio or manually with contactless data cards.[16]

Vehicle coverage by infrared devices ranges from 2.6% in Hamburg to 100% in Milan; the median level of coverage is 6% (Berlin). Responding agencies use infrared devices from Dilax, Red Pine, and UTA.

Five agencies use other forms of APC. Athens OASA counts passengers on one of its metro lines with thermal counting devices. Milan uses photovoltaic cells in the floors of its buses; and Stockholm's passenger counting technology (called ATR) uses photo cells on 10% of its light rail and bus fleets. Montreal has Microtronix treadle mats, a contact APC, in 15% of buses. Budapest estimates bus ridership by weighing 25% of their buses. These buses are fitted with pneumatic springs; an electronic system estimates the number of passengers aboard the bus by gauging the

[14] Dilax Intelcom GmbH promotional materials for IRS-946S Door Sensor and INP-976/INP-994 Input Module.
[15] Dilax Intelcom GmbH promotional materials for BBM-2 Black Box Master.
[16] Dilax Intelcom GmbH promotional materials for DMT-962 Data Modem Terminal.

pressure on the springs. The number of passengers entering and exiting is estimated from the time spent at stops. Prague plans to implement similar weighing devices in their buses this year.

Passenger Counting by Mode

Metro

Twenty agencies with metro service responded to the survey. Of these,

- 15 count passengers manually.
- 11 count passengers through ticketed entries.
- Six count passengers with Automatic Passenger Counting devices.

Bus

Of 12 responding agencies with bus service,

- Ten count passengers manually.
- Six count passengers with Automatic Passenger Counting devices.
- Three count passengers through ticketed entries.

Other

Manual staff counts and ticket counts are used to count passengers using Athens OASA's trolley service, Miami's automated guideway, and Sydney's commuter rail. Los Angeles counts light rail passengers manually. Stockholm's light rail uses photo cells in its ATR passenger counting system.

System Coverage and Integration

Station and vehicle coverage ranges from 2.6% in Hamburg to 100% in seven systems (Mexico City, NYC Bus, NYC Subway, Glasgow, Miami, Prague Metro, and San Francisco's BART). Three agencies (Hamburg, Portland, and Los Angeles) can move equipment as needed. All technologies in use are at least 95% accurate; AFC gates and manual surveys are reportedly at least 99% accurate.

Several agencies have integrated passenger counting with other data collection systems:

- Three agencies' systems (Hong Kong MTR, Prague, and Hamburg) are integrated with service quality or on-time performance (OTP) measures.
- Four systems (Athens OASA, Milan, Montreal, and Portland) are integrated with AVL. NYC Bus plans to integrate passenger counting with AVL in the future.
- Prague also integrates counting with vehicle speed and fuel usage.
- Los Angeles is planning to integrate counting with an automatic vehicle maintenance system.

- Milan's system is integrated with passenger announcements and wait times.
- Stockholm's system is integrated with traffic control and maintenance systems. It also provides vehicle kilometers, vehicle speeds, and travel time between stations.

Data Provided

Passenger counting technology provides agencies with several types of information for analysis. Among survey respondents, it is most commonly used to provide data on passenger entries and exits by station/stop and by time of day. Eleven agencies count ridership by station or stop; nine agencies count ridership by time of day; four estimate vehicle loads; and 12 agencies collect other data. Other types of data collected include ridership by route or line, ridership by ticket or fare type, passenger entries by gate, passenger kilometers, vehicle kilometers, vehicle speeds, station-to-station passenger volumes, origin/destination (O/D) patterns, on-time performance, and revenue. Accuracy of data ranges from 70% to 99% across agencies, with a median of 97% accuracy.

Survey responses suggest that technologies are fairly flexible and capable of yielding the type of data agencies require, despite supposedly differing respective abilities of different technologies. For example, TCRP says Automatic Passenger Counting devices are better suited to collecting disaggregate data than ticket-based systems are.[17] However, seven of nine responding agencies using ticket-based systems collect data on disaggregate levels as well as on aggregate levels with ticket-based technology.

Use of Data

Various analyses are produced from passenger counting data. Of 21 responding agencies:

- Sixteen agencies produce analyses of ridership.
- Seven agencies analyze on-time performance.
- Three agencies analyze revenue.
- Other uses of data include generating trip diagrams; updating schedules; revising service; forecasting budgets and service requirements; determining seating/standing capacity; and generating performance reports.
- Origin/destination analysis is done with data from technology in 11 agencies; other agencies typically use data from manual surveys for this.

Data are stored from 60 days (Glasgow) to 30 years (Budapest Metro). Data are stored a median of five years. Hong Kong, New York City Bus, New York City Subway, São Paulo, Athens, and Sydney archive some or all passenger counting data.

[17] TCRP 29, pp. 11-13.

Results of Technology

The principal service issues that passenger counting technology has identified are the need to provide more service (five agencies), to track changes in passenger demand (three agencies), and to track on-time performance issues (three agencies).

Four agencies reported problems with equipment. Mexico City and San Francisco's BART reported maintenance issues with turnstiles and faregates, resulting in unusable machines, inaccurate data, or unavailable data until repairs were made. Montreal reported maintenance and accuracy issues with its treadle mats, and Taipei experienced some data loss with its AFC gates.

Fourteen of 15 respondents say technology has helped to improve metro service provision. This has primarily been accomplished by agencies' improved ability to match service to demand (12 agencies). Other improvements include setting targets for passenger journey on-time, conducting special studies (e.g., Bicycles on BART), improving customer information, and expanding AFC capacity.

Plans to Upgrade

Fifteen of 25 agencies are considering installing new passenger counting technology. Montreal has installed doorway infrared devices in 120 vehicles, and plans to commission this system by 15 April 2003; 50 more vehicles will be equipped with infrared technology by June 2003. Two agencies (Los Angeles and Toronto) are considering implementing infrared counting technology; four (Mexico City, São Paulo, Budapest Metro, and Sydney) are considering smart card systems; and five are considering other automatic devices, including centralized ATS monitoring, load measuring devices, device scanners, and implementation or expansion of APC systems. Milan plans to install ticket-reading equipment at metro exit gates, for origin/destination analysis.

Findings: Individual Agency Responses

Berlin, Germany — Metro

OVERVIEW

Berlin counts passengers on an irregular basis. Passengers are counted entering and exiting vehicles, entering and exiting stations, and transferring between routes or lines.

CAPACITY

Technology and Methods: Staff manually estimate passenger counts from platforms. Six percent of Berlin's cars are permanently outfitted with infrared doorway counting technology, to count passengers entering and exiting vehicles. In these cars, doors are fitted with three or four pairs of infrared sensors, which count passengers and determine whether they are entering or exiting. Data are sent to a processing unit in the lead car; they are later uploaded onto a computer at the terminal station, and relayed to headquarters in one to two days. This technology is in daily operation on eight six-car trains of large profile and on three eight-car trains of small profile. It was produced by Dilax Intelcom GmbH, and has been in use since 2000.

Future Plans: Berlin is satisfied with current technology and anticipates only software upgrades.

Diagnostic Use of Information: Data are stored for 10 years and used to analyze loading by line and by time. Origin/destination analysis is conducted through passenger surveys.

EVALUATION

There is a 5% error rate for infrared doorway counting technology. Continuous manual counts are conducted for comparison.

Hong Kong (MTR) — Metro

OVERVIEW

Hong Kong MTR counts passengers entering and exiting stations daily. Passengers transferring between routes or lines are counted two or three times per year.

CAPACITY

Technology and Methods: Passengers entering and exiting stations are counted by Ascom & Thorn ticket machines and AFC gates by CGA, Cubic, ERG, and CTS. Transferring passengers are counted through manual estimates. Passenger counting is integrated with service quality measures to determine the number of passengers affected by delays.

Diagnostic Use of Information: MTR determines origin/destination and entry/exit time through entry and exit gates. Data are used to generate ridership and on-time performance reports.

EVALUATION

AFC gates are nearly 100% accurate. Performance has been improved by using reports to set targets for on-time performance.

Mexico City, Mexico — Metro

OVERVIEW

Mexico City counts passengers entering and exiting stations daily. Passengers entering, exiting, and aboard vehicles are counted when indicators denote that service capacity may need adjustment. Transferring passengers are also counted.

CAPACITY

Technology and Methods: Passengers entering, exiting, and on vehicles are counted by manual staff estimates. Passengers entering and exiting stations are counted from ticketed entry turnstiles that are located at all stations. These are read by a staff member at the end of the service period, and are communicated by phone to the Line Communication Center. The turnstiles are by Monotels, with an 8085 microprocessor (1980) and an 8031 microprocessor (1990). Transferring passengers are counted by origin/destination surveys.

Future Plans: Mexico City is developing plans to install a contactless smart card system. The maker and installation dates are not yet determined.

Diagnostic Use of Information: Data are stored for at least five years. Passenger counts are used to forecast ridership for the annual budget.

EVALUATION

Turnstiles are designed not to admit passengers when counting function is broken, so counting accuracy is high. Turnstiles require high maintenance. Passenger counting has helped improve service provision by being able to forecast required service.

New York City, USA (Bus) — Bus

OVERVIEW

New York City Transit Bus regularly counts passengers entering, exiting, and on vehicles (there were 250 passenger counts conducted in 2002). Passengers transferring between routes or lines are counted on an as-needed basis.

CAPACITY

Technology and Methods: Manual "ride checks" are performed for all counting categories, by Traffic Checkers (manual surveyors) who ride buses and record all boardings and alightings and derive on-board loads; for "point checks," Traffic Checkers stand at stops and estimate bus loads. In addition, MetroCard fareboxes are present on all buses. These count passengers entering vehicles, but do not identify boarding locations. MetroCard equipment is produced by Cubic.

Future Plans: Automatic passenger counting technology has been proposed on a pilot basis. Testing is expected to begin in the near future. Automated vehicle locator systems are being developed, with implementation expected in several years.

Diagnostic Use of Information: Manual counts are retained for six years. Origin/destination analysis is conducted occasionally through customer surveys, which are very labor intensive.

EVALUATION

MetroCard has very high accuracy. Traffic Checkers are reviewed through field supervision. Passenger counting has helped to identify the need for service improvement, including running times and the need for schedule adjustments, i.e., adding and reducing trips.

New York City, USA (Subway) — Metro

OVERVIEW

New York City Subway regularly counts passengers entering and exiting stations, and on-board trains (there were 2,600 counts in 2002). Passengers transferring between routes or lines are counted on an as-needed basis.

CAPACITY

Technology and Methods: Manual counts are performed for all counting categories. For each check, Traffic Checkers (manual surveyors) stand on platforms count passengers departing on trains over a five-hour period. Passengers entering and exiting stations are counted on stairways. MetroCard turnstiles also count passengers entering and exiting all stations. MetroCard equipment is provided by Cubic.

Future Plans: In several years, New York City Subway plans to have centralized monitoring at a Rail Control Center. Automatic train supervision systems will be implemented as well.

Diagnostic Use of Information: Manual counts are retained for six years. Origin/destination analysis is conducted occasionally through customer surveys, which are very labor intensive. In addition, NYC has a computer model that infers origin/destination patterns by linking together successive MetroCard origin swipes.

EVALUATION

MetroCard has very high accuracy. Traffic Checkers (manual surveyors) are reviewed through field supervision. Passenger counting has helped to identify the need for service improvement, including running times, potential new markets, and obsolete markets.

São Paulo, Brazil — Metro

OVERVIEW

São Paulo occasionally counts passengers aboard vehicles and transferring between routes or lines. Passengers entering and exiting stations are counted daily.

CAPACITY

Technology and Methods: Passenger counts are estimated by ticketed entries to stations. For ticket collection, the system has 636 access gates by Edmonson. Passengers on vehicles and transferring between routes or lines are counted manually by staff. São Paulo has 228 vending machines that were manufactured in the 1990's.

Future Plans: São Paulo expects to implement a smart card fare collection system, which will perform passenger counts. The system bid is being prepared.

Diagnostic Use of Information: Data are stored indefinitely and have been since the metro's inception. Timetables and passenger demand prediction reports are produced. Origin/destination analysis is performed through a sampling basis in stations during certain hours.

EVALUATION

Passenger counting data have helped to identify overload points. Data accuracy for origin/destination analysis is more than 95%.

Athens, Greece (Attiko) — Metro

OVERVIEW

Every two months, Attiko counts passengers aboard vehicles on the most heavily loaded section of each line. Passengers entering and exiting stations, and transferring between routes or lines, are counted annually.

CAPACITY

Future Plans: Attiko is considering installing new passenger counting technology, but the type is undetermined.

Diagnostic Use of Information: Data are stored indefinitely, but the system only began in 2000. Data are used to determine number of weekday metro trips.

EVALUATION

Counting is used to match service to demand. So far, metro service provision has only been marginally improved.

Athens, Greece (OASA) — Metro, Bus, Trolley

OVERVIEW

When necessary, OASA counts passengers entering, exiting, and on vehicles. Once a year, OASA counts passengers entering and exiting stations, and transferring between routes or lines.

CAPACITY

Technology and Methods: Manual estimates by staff are used to count passengers entering and exiting stations, aboard vehicles, and transferring between routes or lines. Estimates of ticketed entries to stations are used to count daily loads in trolley buses, and for passengers entering and exiting stations. Thermal devices in Line 1 stations also count passengers entering and entering stations. On-board staff count passengers entering, exiting, and on vehicles.

Future Plans: OASA plans to equip 300 buses with Deister GW4005, a load-measuring device, in 2002.

Diagnostic Use of Information: Data are saved for five years.

Boston, USA — Metro, Bus

OVERVIEW

Boston counts passengers entering, exiting, and aboard vehicles; passengers entering and exiting stations; and passengers transferring between routes or lines.

CAPACITY

Technology and Methods: All data collection is done manually.

Future Plans: Boston had considered installing new passenger counting technology as a part of transition to CAD/AVL system, but has since decided against it.

Diagnostic Use of Information: Dedicated outside staff perform counting functions, from which "Load Profile" and "Trip Summary" books for bus counts are prepared. Rail count on/off reports are detailed by hour, 15 minute period, and throughput line volumes.

EVALUATION

Counting is done by dedicated outside staff, and data are considered highly accurate. As a result of counting, Boston has been able to recognize lines at or near capacity, and add new cars appropriately.

Budapest, Hungary (Bus) — Bus

OVERVIEW

Budapest counts passengers aboard, entering, and exiting buses, on an annual basis. Passengers transferring between routes or lines are counted occasionally.

CAPACITY

Technology and Methods: Budapest has an electronic counting system built into 25% of buses. This system calculates the number of passengers on the bus, based on the pressure in the pneumatic springs. Technology is from Knorr-Bremse (1982) and R & G (1996). Passengers boarding and alighting buses are counted on the basis of the stop dwell time. Manual staff counts are used to count transferring passengers.

Diagnostic Use of Information: Data are stored for at least ten years. Ridership numbers are used to conduct computer inquiries such as seating and standing capacity, comparisons of data from other years, and schedule analysis. Origin/destination analysis is done through surveying, which has margin of error of +/- 20%.

EVALUATION

Passenger counting technology is very accurate, with margin of error of +/- 5%. Counts are verified by manual staff count comparisons. Budapest has experienced some data retrieval issues with the technology, since it is affixed to specific buses and routes, and data must be read directly from the devices. However, the technology has helped to improve service, by optimizing distribution of buses between lines, rationalizing networks, optimizing schedules, and displaying bus arrival times at stops.

Budapest, Hungary (Metro) — Metro

OVERVIEW

Budapest counts passengers on vehicles annually. Passengers entering and exiting vehicles, and entering and exiting stations, are counted every five years.

CAPACITY

Technology and Methods: Passenger counts are conducted manually by staff on platforms.

Future Plans: Budapest Metro is planning to introduce a smart card system, used for passenger counting as well as other functions.

Diagnostic Use of Information: Staff currently count passenger entries and exits at every station, by direction and time period. Data are kept for 20 to 30 years, and are used to produce reports on service schedules, statistics, and annual reports. Origin/destination analysis produced from data is 95% accurate.

EVALUATION

Manual counts are 95% accurate and are verified by comparison counts. Counts have identified time periods and locations in need of increased service, allowing Budapest Metro to adjust schedules and improve service.

Glasgow, Scotland — Metro

OVERVIEW

Glasgow continuously counts passengers entering stations, according to ticket type.

CAPACITY

Technology and Methods: The ticketing system was produced by Cubic, in 1987.

Future Plans: Glasgow is planning to install a new ticketing system.

Diagnostic Use of Information: Glasgow uses data to determine systemwide ridership by time of day and ticket type. Data are stored for up to 60 days.

EVALUATION

Passenger counting is nearly 100% accurate. Service issues identified through passenger counting include peak congestion and under-capacity. Passenger counting has resulted in matching peak service to passenger numbers. Fares were also revised to encourage off-peak travel.

Hamburg, Germany — Metro

OVERVIEW

Hamburg counts passengers entering, exiting, and on trains daily.

CAPACITY

Technology and Methods: Hamburg uses infrared doorway counting technology by Dilax on 2.6% of its metro cars (21 cars), to count passengers entering and exiting. The number of passengers on vehicles is calculated from numbers of entering and exiting passengers. The metro cars with infrared technology are in constant operation, though there is no formal plan for rotation of equipment throughout the system. Departure time (in seconds) is integrated into the passenger counting system.

Future Plans: In the next few years, Hamburg plans to install infrared technology in buses.

Diagnostic Use of Information: From the passenger counting data, Hamburg produces reports detailing profit distribution (what lines and stations earn the most money) within the metro.

EVALUATION

Hamburg required 95% accuracy for full implementation of passenger counting technology. Through manual counts, accuracy has been proven to be below that number. It is expected that when this accuracy level is reached, the technology will help to improve metro service provision.

Los Angeles, USA — Metro, Bus, Light Rail

OVERVIEW

Los Angeles counts passengers on its “top 20 lines” every other week. For other “57 potential problem lines,” passengers are counted once every quarter. Passengers transferring between routes or lines are counted once every three years.

CAPACITY

Technology and Methods: On 5% of Los Angeles’s buses, infrared doorway counting technology by UTA has been installed. These vehicles are moved around the network. Other counts are done manually.

Future Plans: Passenger counting technology will be used to plan trips not running the full length of the metro (on shortlines, the most heavily traveled sections). Los Angeles is considering installing passive infrared overhead sensors. There are also plans to integrate passenger counting technology with automatic train supervision.

Diagnostic Use of Information: There is no set policy for length of data storage. Reports produced from data include segment level running time and passenger loads. Origin/destination surveys are conducted.

EVALUATION

For trip level counts, data collected are accurate to within 10%. Passenger load accuracy is within 30%. Through passenger counting technology, Los Angeles has faced issues of scheduling sufficient running time. Los Angeles is "yet to fully capitalize" on passenger counting technology due to the low rate of accuracy.

Miami, USA — Metro, Bus, Automated Guideway

OVERVIEW

Miami counts passengers on and exiting specific vehicles every day. Passengers entering buses and rail stations are counted daily. Passengers transferring between routes or lines are counted daily for all modes.

CAPACITY

Technology and Methods: Passengers aboard and exiting vehicles are counted manually. Bus operators manually account for passenger entries on electronic fare boxes. Electronic turnstiles count rail passengers entering stations. Fareboxes and turnstiles are by Cubic and GFI.

Future Plans: Miami currently has a consultant on staff to study the different passenger counting technologies available and provide a recommended course of action. It is expected that infrared doorway counting technology will be installed to track ridership patterns.

Diagnostic Use of Information: Fareboxes and turnstiles count passengers by time, day, and fare type (pass, cash, token). Miami produces two monthly ridership reports, one quarterly performance report, and one annual report.

EVALUATION

The data collected are quite accurate. Passenger counts are reconciled each month to the revenues collected per mode (bus, heavy rail and automated guideway).

Milan, Italy — Metro, Bus, Tram, Trolley

OVERVIEW

Milan counts passengers onboard vehicles, and entering and exiting vehicles at every stop.

CAPACITY

Technology and Methods: To count passengers on buses, photovoltaic cells in the floor of the bus are used. To count passengers on metros, Milan has infrared sensors at all ticket gates that count passengers as they enter and exit. These sensors were installed in 1990. Manual methods are also used for metro passengers. Passenger counting is integrated with vehicle location, audovisual next-stop announcements, and wait times.

Future Plans: Milan plans to install a ticketing system in some metro stations that will register entries and exits. This will assist origin/destination analysis.

Diagnostic Use of Information: Infrared sensors count passengers by line, time period, and schedule type, and reports on ridership at these levels are generated. Data have been stored since 1999.

Montreal, Canada — Bus

OVERVIEW

Montreal counts passengers entering, exiting, and on buses twice per booking period (approximately 10 weeks).

CAPACITY

Technology and Methods: Counting is conducted on approximately 15% of cars by a treadle mat (Microtronix, 1995). Vehicles equipped with this technology are distributed in order to meet sampling requirements. Vehicle location (GPS) is integrated with passenger counting technology.

Future Plans: In November 2002, Montreal began installation of infrared doorway technology from Init. So far, 120 vehicles are equipped, and the agency expects to equip 50 more vehicles by the end of June 2003. The agency plans to have the system commissioned by 15 April 2003.

Diagnostic Use of Information: Data are stored for two years. Reports produced from data include punctuality, service planning, and ridership.

EVALUATION

Passenger counting technology has a 5% error rate. Checkers are used to measure accuracy.

Portland, USA — Bus

OVERVIEW

Portland counts passengers entering, exiting, and on vehicles on a daily basis. Every one to three years, passengers entering and exiting stations are counted. Passengers transferring between routes or lines are counted every five years.

CAPACITY

Technology and Methods: Portland has installed infrared doorway counting technology (by Red Pine) on 70% of buses[18], which are rotated, to count passengers entering, exiting, and on vehicles. Other counts are performed manually.

Future Plans: Every new bus will come with the devices installed. Eventually 100% of the fleet will be equipped.

Diagnostic Use of Information: Raw data are stored for six months. Summarized data are stored for at least two years. Origin/destination reports are produced every five years. Passenger counting data are used to produce reports on ridership by stop level, route level, trip level, time of day, and systemwide. Infrared doorway counting technology is also used for monthly systemwide bus ridership analysis.

EVALUATION

In 2001, Portland completed a verification study. Technology-counted boardings are 98.8% accurate at the stop and trip levels. Passenger counting technology has improved service provision by allowing fewer overloads, increased ability to address capacity issues, and increased service where needed.

Prague, Czech Republic — Metro, Bus

OVERVIEW

Prague counts passengers on vehicles once a month at selected stations. Passengers entering and exiting vehicles are counted two to three times per year. Passengers entering and exiting stations are counted twice a year at selected stations. Passengers transferring between routes or lines are counted every three years.

CAPACITY

Technology and Methods: All counts of bus passengers are performed manually. Metro passengers are counted manually and with infrared technology. Passengers entering and exiting metro stations are counted by infrared sensors at entrances and exits of ticket areas.

Future Plans: Prague has been testing pneumatic passenger load-measuring units in four buses for eight months. Devices collect passenger load data as well as service information (door open/close times, and vehicle arrival/departure times, relative to timetable), and generally have a 5% difference (for load measuring) from manual counts. Data are processed and transmitted to an onboard computer and subsequently transmitted via radio to a collecting unit in the garage. Equipment, made by JKZ Olomouc, has been installed in 125 buses so far. Software designed for analysis and assessment is expected to be implemented within the year.

[18] Interview with Steve Callas, 21 August 2002.

Diagnostic Use of Information: Data from manual counts are kept for over five years. Infrared data are stored for five years. Customer surveys are also used for origin/destination analysis.

EVALUATION

Through passenger counting, Prague Metro has been able to recognize changes in passenger flows after opening new stations. Passenger counting technology has aided modifications of train flowcharts to better meet needs. Origin/destination analysis and traffic surveys are 89% accurate.

Rio de Janeiro, Brazil — Metro

OVERVIEW

Rio de Janeiro counts passengers entering stations at all stations daily. Passengers exiting six specific stations are counted every day, and passengers at the remaining 25 stations are counted occasionally. Passengers transferring between routes or lines are also counted occasionally.

CAPACITY

Technology and Methods: All stations have automatic entry controls. Six have exit controls as well.

Future Plans: Rio de Janeiro is not planning to install any new passenger counting technology.

San Francisco, USA (BART) — Metro

OVERVIEW

BART counts passengers on vehicles before major schedule changes and when there are significant complaints from train operators or passengers about overcrowded trains. Passengers entering and exiting vehicles and stations are counted daily. Passengers transferring between routes or lines are counted occasionally.

CAPACITY

Technology and Methods: Passengers entering and exiting vehicles are counted by a computerized passenger-flow model by IBM. Automated ticket machines (Data Acquisition System, by Cubic) record passengers entering and exiting stations. Passengers transferring between routes or lines are counted through surveys.

Diagnostic Use of Information: Data systems produce information on passenger entry and exit by time and by station. Data are stored for at least a few years, depending on use and storage capacity. Reports include daily passenger unlinked trips, and occasionally passenger load analysis. Sometimes origin/destination analyses are conducted.

EVALUATION

Passenger counting technology has helped to improve metro service provision, but not to its full potential. Operations still performs manual platform counts to schedule service instead of relying on electronic data from the Passenger Flow Model. Special studies such as Bicycles on BART, Train Loading Analysis, and train data for Fire Egress Analysis. have benefited from a large sample size of data from the Passenger Flow Model, which uses passenger entry/exit ticket data. The electronic data are much more cost-effective, without the need for expensive manual field data collection, and allow for a larger sample size with greater statistical accuracy.

Stockholm, Sweden — Metro, Bus, Commuter Rail, Light Rail

OVERVIEW

At least two or three times per month, Stockholm counts weekday passengers on vehicles at the most heavily loaded points in the system. Weekend passengers are counted at least three to five times per year. At least once every winter, passengers are counted entering and leaving stations.

CAPACITY

Technology and Methods: Today, passengers on the Stockholm commuter trains and metro are counted manually. On the light rail and buses, 10% of vehicles are equipped with ATR, an automatic passenger counting system using photovoltaic cells.

Future Plans: Ten percent of vehicles in all modes will be equipped with ATR.

Sydney, Australia — Commuter Rail

OVERVIEW

Passengers loads on vehicles are measured at selected points on each line at least once or twice per year. Passengers entering and exiting vehicles are counted on an occasional basis. Passengers transferring between routes or lines are counted less than once a year. Passengers entering and exiting "large" stations (43 of 306) are counted daily. Passengers entering and exiting other stations are counted at least once every four years.

CAPACITY

Technology and Methods: Passengers entering and exiting large stations pass through gates (by Cubic) that count automatically. However, passengers entering these stations with luggage, strollers, prams, or in wheelchairs must pass through wider gates that can only be manually counted. All other counts are performed manually.

Future Plans: Sydney expects to install a smart card system by 2005, to track passenger movement throughout the system.

Diagnostic Use of Information: Detailed data are stored for one year and then archived. Summary data are stored for a longer period before being archived. Sydney's technology provides ticket sales, passenger journeys, farebox revenue, entries, and exits. Data are also used to produce reports on ticket sales, trips, and revenue by station, ticket type, and month, and for origin/destination analysis. Sydney has a distance-based fare system with single, return, weekly and periodical tickets having an origin and destination station. In the morning peak, 80% of exits are from automatic gated stations. The origin of each ticket and other information is recorded when the magnetic striped ticket is passed through the automatic gate.

EVALUATION

Data collected are fairly accurate. Automatic gate use has been measured in the past by comparing against a manual count. However, at stations with automatic gates, 90-95% of passengers uses these gates. Passenger counting technology has helped to improve metro service provision, but most decisions are based on data obtained through manual counts.

Taipei, Taiwan — Metro

OVERVIEW

Passengers on vehicles are counted monthly. Passengers entering and exiting stations are counted daily.

CAPACITY

Technology and Methods: Passengers entering and exiting stations are counted through estimates from ticketed entries to stations. AFC equipment is by Alcatel-CGA (1986) and OMRON (1998).

Diagnostic Use of Information: Passenger entry and exit counts are available by time and station, and number of journeys by ticket type. Origin/destination analysis is performed with data collected. Data are stored for years.

EVALUATION

Data collected are nearly 100% accurate. This is verified by simulating revenue service. Passenger counting technology has helped improve service provision. Through passenger counting analysis, Taipei estimates and adjusts how many pieces of AFC equipment are required, as well as how many employees and cars are needed for stations.

Toronto, Canada — Metro, Bus

OVERVIEW

Toronto counts passengers on vehicles three times per year. Passengers entering and exiting stations are counted once a year. Passengers entering and exiting vehicles are counted every 18 months.

CAPACITY

Technology and Methods: All counts are performed manually by staff on platforms.

Future Plans: Fifty infrared passenger counting units are being tested.

Diagnostic Use of Information: Data are stored for over 10 years, and are used to produce reports on ridership activity (boardings and alightings), maximum hour volumes, observed running times, and headways.

EVALUATION

Passenger counting technology has helped to improve metro service provision. The manual count program is an integral part of route and system planning in Toronto. Maximum hour loads at peak point locations for each route are compared against loading standards, and adjustments to service levels are made, subject to the availability of vehicles and budgeted mileage. Observed running and layover times are compared to scheduled service, and times are adjusted as needed.

PART TWO:

SERVICE MONITORING TECHNOLOGY

Introduction

Transit agencies rely on information about system operations and schedule adherence for the provision of high-quality service. In the last ten years, Advanced Public Transportation System (APTS) technologies have improved upon the capabilities of manual and older automatic monitoring systems. With capabilities ranging from Automatic Vehicle Location to Automatic Train Operation, APTS-derived information helps transit agencies better manage short-term operations and plan future service adjustments. Transit agencies are increasingly recognizing and taking advantage of the many applications and benefits of these newer service monitoring technologies. For example, improved data collection and analysis for Portland's bus service identified excess recovery time in the schedules (and its causes); correcting this will allow them to save approximately $7 million annually.[1]

Overview of Topics Covered

This report provides an overview of the technologies that transit agencies worldwide are using to monitor service. Major issues reviewed in the report include:

- Types of monitoring technology in use.
- Coverage of vehicles and stations by monitoring technology.
- Data provided by technology, and reports produced from data.
- Treatment of data, including level and frequency of collection; storage; accuracy and verification; dissemination; and integration with other data collection systems.
- Effectiveness of service monitoring technology in improving service.
- Plans to expand or upgrade service monitoring systems.

Types of Service Monitoring Technology and Their Capabilities

There are many ways of monitoring transit service, whether manually or with technology. Traditional manual methods include dispatching staff or employing dedicated staff to monitor transit service. Older route or track-based monitoring technologies may take several forms, including in-house solutions for regulating headway, signaling systems that show track occupation, and computer systems that interpret information from other route or track-based sources. Agencies may also monitor service with cameras. Finally, agencies are increasingly taking advantage of newer Automatic Train Supervision and Automatic Vehicle Location technologies.

Automatic Train Supervision (ATS)

Depending on the system, ATS capabilities can include train location monitoring, optimizing schedule adherence, and adjusting train speed and route selection. More automated ATS systems can

[1] Steve Callas, "Using Archived ITS Data to Improve Transit Operations and Performance," Tri-Met, Portland, Oregon.

predict the probability of conflict (e.g., with a merge) and adjust dwell time, departure times, and speed.[2] They may even provide completely automated train operation (ATO).

ATS can also interface with Automatic Train Protection, Automatic Vehicle Identification, and Passenger Information Systems. With the implementation of ATS, many agencies have achieved overall improvement in operations and customer service.

Automatic Vehicle Location (AVL)

Automatic vehicle location has become increasingly sophisticated over the last 20 years. It uses various methods of detection, such as global positioning systems (GPS); signposts (wayside radio beacons); dead reckoning (a technique that deduces location from speed and direction); and Loran-C (supported by land-based radio navigation).[3]

Other information may be collected automatically (e.g., route number and direction, trip number, passenger counts, maximum speeds) and drivers may enter events in on-board computers (e.g., traffic delays, fare evasion, overload).[4] In Portland and Budapest, AVL has identified problems with specific vehicle operators.

Alone, AVL can offer real-time vehicle location and schedule adherence at a particular point or on a route. If data is carefully analyzed and strategically used, AVL can assist in improved service; enhanced on-time performance; and real-time passenger information and announcement systems.

Research Efforts

In August 2001, New York City Transit surveyed metros worldwide on the nature and success of their service monitoring systems. The survey asked about agencies' use of seven monitoring methods, treatment of data provided by these means, and overall success of monitoring programs. The methods inquired about were:

- Automatic Train Supervision (ATS).
- Automatic Vehicle Location (AVL).
- Other systemwide track or route-based monitoring.
- Monitoring by dispatchers.
- Monitoring by separate monitoring staff.
- Camera monitoring.
- Other service monitoring techniques agencies are using.

[2] "Rail Transit Capacity," Transit Cooperative Research Program (TCRP), *Synthesis 13*, 1996, p. 23.
[3] "AVLC Technology Today: A Developmental History of Automatic Vehicle Location and Control Systems for the Transit Environment," by David A. Cain and Barry R. Pekillis, 1993, p. 581.
[4] "Using Archived ITS Data to Improve Transit Operations and Performance," Steve Callas.

New York City Transit also conducted a literature review of issues surrounding service monitoring. The bulk of available information was about ATS and AVL, reflecting great interest in these technologies within the industry.

Twenty-nine agencies responded to the survey.

Table IV-1
Questionnaire Respondents

Agency	Service Described
Berlin, Germany (BVG)	Metro
Hong Kong (MTR)	Metro
Mexico City, Mexico	Metro
New York City, USA (Bus)	Bus
New York City, USA (Subway)	Metro
São Paulo, Brazil	Metro
Tokyo, Japan	Metro
Athens, Greece (Attiko)	Metro
Barcelona, Spain	Metro, Bus
Boston, USA (MBTA)	Metro, Bus, Trolley
Budapest, Hungary (Bus)	Bus
Budapest, Hungary (Metro)	Metro
Glasgow, Scotland	Metro
Hamburg, Germany	Metro, Bus
Jersey City, USA (PATH)	Metro
Miami, USA	Metro, Bus, Automated
Milan, Italy	Metro, Bus
Montreal, Canada	Metro, Bus
Portland, USA	Light Rail, Bus
Prague, Czech Republic (Bus)	Bus
Prague, Czech Republic (Metro)	Metro
Rio de Janeiro, Brazil	Metro
San Francisco, USA (BART)	Metro
Singapore	Metro
South Africa	Commuter Rail
Sydney, Australia	Commuter Rail
Taipei, Taiwan	Metro
Toronto, Canada (Subway)	Metro
Toronto, Canada (Surface)	Bus, Streetcar

The objective of this research effort has been to highlight key aspects of service monitoring technology such as automatic train supervision, automatic vehicle location, and staff-based monitoring techniques, and to examine how these are used to understand and resolve service issues. These issues are of particular importance to New York City Transit as it considers the next generation of service monitoring systems.

Findings: Summary of Responses

Technologies in Use

Data Provided and Uses of Data

Agencies use a variety of methods to determine the reliability and punctuality of their vehicles. While ATS and AVL are the most commonly used technologies, most agencies use a combination of methods, including both automated and manual techniques. Service monitoring technology (especially ATS and AVL) is used for on-time performance (OTP) analysis more than for other purposes, but it may also provide continuous location information, vehicle loads, vehicle identification, and headway adherence. Of the 29 respondents,

- Fifteen agencies use ATS.
- Seventeen agencies use AVL.
- Four agencies use other track or route-based systems.
- Twelve agencies have dispatchers monitor service.
- Eleven agencies have separate staff monitor service.
- Four agencies monitor service with cameras.
- Three agencies use other methods.

Some agencies have technologies mentioned above, but do not use them for service monitoring purposes. For example, some agencies, including Mexico City, San Francisco, and Taipei, have camera surveillance, but do not use it for service monitoring. Also, Boston has a route-based monitoring system that is not currently in use.

Overview of Data Collection, Distribution, Retention, and Evaluation

Procedures for data management vary, but there are trends in agencies' use of data. Most data are gathered continuously, except for data collected by monitoring staff, which tend to be gathered daily. AVL data in particular are likely to be collected continuously; 13 of the 17 agencies currently using AVL collect data continuously, and agencies with plans to implement AVL intend to do so.

Most agencies (16 of 28 respondents) gather data at varying levels of detail. The ability to collect disaggregate data, and to control for many variables affecting service, can be very useful in identifying causes (and potential remedies) of service problems. Agencies gather and analyze data by line, route, division, station, branch, direction, run, time period, vehicle, sub-fleet, and node, as well as systemwide. For ATS, AVL, and dispatchers, most agencies gather and analyze data by line. Those agencies gathering data systemwide primarily use ATS for this purpose (five of ten agencies).

Many agencies disseminate data from technology via intranet, through a central group or department, or manually. Agencies also use public websites (New York City Bus, New York City Subway, Boston), displays (Tokyo, Barcelona, Miami), handheld computers (Miami), fax (Milan), and telex

(Milan) to disseminate information. Information from service monitoring is released as performance indicators (New York City), and is issued upon request by other departments (Boston). At 14 agencies, multiple means are used to disseminate data. For example, in Taipei, a Central Control Room computer collects ATS data, which are compiled by a controller and emailed to the planning department. At BART, a consulting form uses data to evaluate performance; data are compiled into reports, which are widely distributed, as well as being posted on an internal PC network and displayed in chart format in offices, shops, and public areas.

Storage of data ranges from one week (Tokyo) to ten years (Sydney), with a median retention of one year. Five agencies (Hong Kong MTR, New York City Bus, New York City Subway, Portland, and Toronto Surface) archive data.

Most agencies report that data from their technology is accurate. (Rather than giving percentages, most respondents gave a subjective assessment of accuracy, e.g., "very accurate," or gave indications of equipment's temporal precision, e.g., "within five seconds.") Nine agencies verify data manually, and three agencies (Berlin, Sydney, and Toronto Surface) have computers verify data. Many agencies do not indicate how or whether they verify the information, and two (Taipei and Portland) report that they do not officially verify it.

Automatic Train Supervision (ATS)

Methods/Technology

Fifteen agencies use ATS systems, and New York City Subways is developing ATS. Miami uses ATS to a limited extent.

Respondents' ATS equipment ranges in year of manufacture from 1965 to 2000, with a median year of 1993. Agencies use ATS equipment by many different manufacturers, and multiple agencies use Alstom and Westinghouse. Toronto Surface was the only responding agency that developed its system in-house.

Coverage

Of the 15 agencies monitoring vehicles with ATS, 11 monitor all of their vehicles. Barcelona monitors 60% of vehicles, and Miami monitors a random sample of vehicles. New York City Subways plans to have 100% coverage upon full implementation of ATS.

Ten agencies monitor all stations or stops with ATS. Barcelona monitors 60% of stations, Portland monitors one-third, and Toronto Subway monitors 20%.

Nine agencies (Hong Kong, São Paulo, Athens Attiko, Hamburg, Prague, Rio de Janeiro, San Francisco, Singapore, and Taipei) monitor all vehicles and all stations or stops with ATS.

Data

Nine agencies use ATS to provide arrival and departure times and other OTP information; this is its principal use among agencies. Singapore's ATS system includes AVL, route and track-based monitoring, and dispatching; it is also used to provide schedule deviations. San Francisco's ATS system also provides continuous vehicle location information, Hamburg's system helps insure intermodal connections, and San Francisco's ATS provides data on equipment status. Athens Attiko notes that their ATS is not currently used to capacity; data cannot be processed as required for daily systems analysis.

Most agencies report that their technology provides accurate data. Toronto Surface verifies accuracy of ATS data by computer. Singapore and Toronto Subway verify data manually, and Miami verifies data statistically. Portland and Taipei do not officially verify ATS data, although ongoing comparisons indicate that they are very accurate. Of 15 respondents, four agencies (Portland, San Francisco, Singapore, and Taipei) disseminate data through an intranet, nine process data through central groups, and two agencies (Miami and Taipei) distribute data manually.

Automatic Vehicle Location (AVL)

Methods/Technology

Seventeen of 22 responding agencies use AVL. New York City Bus and Miami are developing AVL programs. Singapore's AVL is a function of ATS. Prague Bus is undergoing a trial operation of GPS on about 200 vehicles. Montreal uses AVL in its buses, but not in its metro (which uses manual methods for service monitoring).

Respondents' AVL equipment ranges in year of manufacture from 1990 to 2001, with a median year of 1998. Agencies use AVL equipment by numerous manufacturers, with several agencies using Siemens equipment. Toronto Surface's system was is the only reported system developed in-house. Milan uses a "Train Describer" system in its metro, and a "centralized regulation and control system" for surface lines; the latter provides loading conditions as well as vehicle location and intervals.[5]

Coverage

Of the 17 agencies using AVL, 11 monitor 100% of vehicles. Boston monitors all rail vehicles, and about 3% of buses; older buses are currently being retrofitted with GPS systems, and new buses will be equipped.

Six agencies (Barcelona, Miami, Montreal, Portland, Prague Metro, and Toronto Subway) monitor 100% of stations/stops, as well as monitoring all vehicles, with AVL.

Data

AVL is principally used to provide arrival/departure times and other OTP information, (11 agencies). AVL provides continuous location information for three agencies (Barcelona, Montreal, and Sydney), and passenger load information for three agencies (Milan, Montreal, and Portland). Berlin's system provides statistics on punctuality and breakdowns, as well as being integrated with passenger information. Mexico City's system compensates for late trains, facilitates terminal maneuvers, and indicates when personnel are on tracks. In Portland and Budapest, AVL has identified issues with drivers. Portland's system collects stop-level data automatically (about 500,000 records per day), and event data (about 25,000 records per day) are entered by bus operators.

Most agencies find AVL data accurate, but Toronto Subway plans to replace its current fixed-block system with a more accurate system. Berlin verifies AVL data by computer, and Boston and Jersey

[5] Azienda Trasporti Milanesi (ATM) website (http://www.atm-mi.it/eng/tecnolo/SISTEMI/psiste.htm).

City (PATH) verify data manually. Seven agencies disseminate AVL information through intranets, and four agencies process data through central groups. Berlin disseminates data in real time, Boston dispenses data to the planning department upon request, and Milan uses telex and fax to disseminate data. In Portland's system, after uploading data from bus CPU's to the network, schedules and actual times are "matched" and entered into a relational database; this is later studied by analysts, who produce reports that determine variables responsible for service incidents.[6]

Other Systemwide Track/Route-Based Monitoring

Methods/Technology

Four responding agencies (Barcelona, Budapest Metro, Toronto Surface, and Glasgow) use other systemwide track or route-based monitoring systems. In Budapest Metro and Glasgow, this is the sole service monitoring technology used (other than manual methods).

Barcelona's system, which regulates headway and provides data on times, was developed in-house. Budapest Metro's system (Integra Domino, 1970) has panoramic boards showing track occupation; traffic checkers gather information from these daily. Toronto Surface's Route Management System is an Excel-based software application (developed in-house) that links to AVL data. Glasgow's ADtranz system, installed in 1996, is part of their signaling system, and it shows track occupation and gives arrival times at stations.

Coverage

Of four agencies using track or route-based technology to monitor vehicles, three (Barcelona, Budapest Metro, and Glasgow) monitor 100%. Toronto monitors 77% of buses and 82% of streetcars.

Barcelona and Budapest Metro monitor all stations with these systems, and Glasgow monitors one of its 15 stations.

Data

Barcelona's system provides OTP and continuous vehicle location, and regulates headway. Budapest Metro's system provides data on vehicle traffic, passenger loads, and unusual incidents; it also determines load capacity of vehicles and escalators. Glasgow's system provides track occupation, continuous OTP data, and a more customer-focused understanding of delays. Toronto's system generates reports from AVL data on any combination of routes and time frames.

Budapest Metro reports 80% accuracy, verified through manual spot checks. Glasgow finds their data very accurate. Barcelona disseminates data via intranet, and Glasgow and Toronto Surface disseminate data both manually and via intranet.

[6] "Using Archived ITS Data to Improve Transit Operations and Performance," Steve Callas.

Dispatchers

Methods/Technology

Twelve agencies have dispatchers monitor service provision. Dispatchers are often a source of service monitoring data, although data collection is generally not a dispatcher's primary job.

Two agencies reported on their dispatcher equipment. Budapest Bus's equipment is manufactured by VHF and OTE (1998). Prague Metro's equipment is part of their UniControls (1998) PC network.

Coverage

Vehicle coverage by dispatchers ranges from 60% (Budapest Bus and Prague Bus) to 100% (Jersey City PATH and New York City Subways). Budapest Metro dispatches staff to all stations and Jersey City (PATH) dispatches staff to all vehicles and stations. Prague Bus dispatches staff to about 13% of its stops. Boston and New York City Bus dispatch staff to key locations, such as terminals and key intermediate locations; Boston also has dispatchers at schools (for supplemental bus trips). Montreal and Prague Metro dispatch staff as needed for specific situations.

Data

Dispatchers provide agencies with various data, including OTP, car identification, and vehicle loads. Boston reports that information from dispatchers is accurate; Prague Metro reports that accuracy varies and is based on information from drivers. Jersey City (PATH) and Budapest Bus verify data manually. Six agencies (New York City Bus, New York City Subway, Budapest Metro, Jersey City PATH, Prague Bus, and Prague Metro) distribute data from dispatchers manually; Boston dispenses data to the planning department upon request.

Separate Monitoring Staff

Methods/Technology

Eleven agencies have separate staff monitor service.

Coverage

Vehicle coverage by separate monitoring staff ranges from 2% of bus trips (New York City Bus) to 100% of peak service (Sydney) and 100% of all trains (Jersey City PATH). Two respondents (Mexico City and Jersey City PATH) have separate staff monitor all stations.

Data

Monitoring staff provide various data, including information on OTP and service quality. New York City Bus and New York City Subway data are verified manually; Milan verifies by viewing videotapes in slow motion; and Sydney uses computers to verify data. Most agencies find information from monitoring staff very accurate. Four agencies disseminate information manually (Mexico City, New York City Bus, New York City Subway, and Athens Attiko), three through a central group (Boston, Jersey City PATH, and Sydney), two via intranet (Singapore and Sydney), and Miami uses handheld devices to distribute data. New York City Bus and New York City Subway make some of these data available on their customer website.

Camera Monitoring

Methods/Technology

Four agencies (São Paulo, Prague Metro, Prague Bus, and Milan) use camera surveillance to monitor service. Prague Bus's camera monitoring systems are in trial use.

Camera equipment ranges in year of manufacture from 1990 to 1998. Manufacturers include Marconi, Thomson, Elbex, and Elvija.

Coverage

Prague uses cameras to monitor 5% of buses and 100% of trains. (São Paulo and Milan do not report vehicle coverage statistics.) São Paulo and Milan monitor all stations with cameras, which operate continuously. Prague Metro has cameras in all stations, which are used as needed.

Data

São Paulo uses cameras to monitor passenger flow, platform occupation, and proximity of trains to platforms, and to ensure safe departures. Milan uses cameras to monitor vehicle and platform loads, and verifies data by slow-motion reviews of videotape. In Prague Metro, dispatchers monitor cameras to evaluate operation, passenger frequency, and safety.

Other Methods

Methods/Technology

Three agencies report using other technologies or methods than those included in the survey. In Hamburg, drivers determine vehicle reliability and punctuality. Prague Metro's UniControls PC network (1998) monitors switch and signal condition for preventive maintenance. Tokyo uses heat and vibration sensors for preventive track maintenance.

Coverage

Hamburg's drivers monitor all vehicles and some stations. Prague Metro's equipment monitors its entire system. Tokyo monitors 15 stations with its sensors.

Data

In Hamburg, direct communication between drivers and control centers provide OTP information for each station and delay information (to facilitate intervention); data are considered accurate and are processed through a central group. Prague Metro reports 100% accuracy with its switch and signal monitoring equipment. Data from Tokyo's sensors are considered very accurate and operate continually to produce operational statistics.

Integration with Other Systems

Thirteen agencies integrate other data collection systems with service monitoring, and five do not. Three agencies integrate service monitoring with passenger counting, and three with customer information. Agencies demonstrate a number of combinations of service monitoring functions with other technologies and functions.

- Barcelona integrates customer information and station wait times with service monitoring.
- Glasgow's track-based monitoring is part of its signaling system.
- Hamburg's ATS is integrated with train announcements, displays, and a system to ensure intermodal transfers.
- Milan's AVL is integrated with passenger counting, wait time, and next-stop announcements.
- Montreal's AVL is part of the passenger counting system on buses.
- San Francisco integrates service monitoring with performance measures such as train/patron on-time, delays, service quality, and availability of station equipment and vendors.
- Sydney's AVL is integrated with train radio and train control.
- Toronto Subway integrates vehicle communication, service quality with service monitoring.
- Toronto Surface integrates vehicle communication, service quality, and emergency alarms with AVL and its route management system.

Plans to Upgrade

Eighteen of 27 respondents are considering installing new technology. Six agencies are considering installing ATS systems, seven are considering AVL, and three are considering other technologies. Potential suppliers include Siemens, Bombardier, Apex GPS, Init, Signal Ltd., Train Location System, and Alstom. Agencies' future plans overall indicate continuing and/or expanding present uses of technology, and continuing the emphasis on ATS and AVL and OTP indicators. Agency plans include:

- Implementing AVL (New York City Bus).
- Implementing ATS (New York City Subway).
- Expanding ATS to provide trip data and expanding camera monitoring (São Paulo).
- Implementing ITS for real-time data (Boston).
- Implementing ATS (for times, headway) and AVL (for train identification) (Jersey City PATH).
- Integrating APC with service monitoring (Miami).
- Expanding ATS to provide equipment status (San Francisco).

- Expanding ATS and AVL to provide train identification (Toronto Subway).
- Implementing GPS (Budapest Bus, Prague Bus, and Toronto Surface).

Results of Using Service Monitoring Technology

Agencies use data from technology to conduct a wide variety of analyses. Twelve agencies use more than one service monitoring technology, and 24 agencies use more than one service monitoring method (including technology and manual methods), to identify these needs and issues. ATS and AVL are the most common sources of these data.

- ATS and AVL are each used to identify OTP issues in seven agencies and assess headway adherence in three agencies.
- Other analyses from ATS data include revenue car kilometers, car kilometers between failures, signaling performance, and speeds.
- Other analyses from AVL data include statistics on breakdowns, passenger loads, and vehicle performance.

The primary issues identified by technology involve OTP — understanding delays and suspensions of service, and their causes. Understanding this information facilitates scheduling, service planning, operations, and project development.[7] Service monitoring technology has also identified issues of equipment failure, safety concerns, and other service problems.

As a result of such analyses, 22 of 24 respondents say technology has helped improve service provision. In Mexico City and Athens Attiko, technology was installed concurrently with development of the systems, so improvements cannot be measured. Taipei reports that technology has helped match Medium Capacity Transit service to demand, but has not improved Heavy Capacity Transit service.

Among the 22 respondents reporting improved service, the most common uses of data were for schedule and service adjustments (14 agencies) and resolution of delays and other problems (nine agencies). In addition, 14 agencies reported other benefits of service monitoring data, including:

- In Berlin, AVL improves customer service information.
- AVL in Budapest's buses increases traffic control efficiency and improves customer service information.
- Hamburg uses ATS to plan service during track work; similarly, Toronto (Surface) uses AVL and route-based technology for contingency planning during construction on roads.
- Portland's bus AVL helped identify excess recovery time in schedules and operator-specific issues; addressing identified problems will save approximately $7 million dollars annually, while maintaining or increasing levels of service.[8]

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[7] "Using Archived ITS Data to Improve Transit Operations and Performance," Steve Callas.
[8] "Using Archived ITS Data to Improve Transit Operations and Performance," Steve Callas.

- In Prague Metro and Tokyo, monitoring equipment for preventive maintenance, together with service monitoring, improves service reliability.

The accuracy and abundance of data provided by service monitoring technology—especially ATS and AVL—help agencies determine what issues need to be addressed. Reinforced by manual staff monitoring, monitoring technologies are enabling transit providers to provide more efficient and effective service.

Findings: Individual Agency Responses

Berlin, Germany — Metro

OVERVIEW

Berlin uses Automatic Vehicle Location (AVL) to determine the punctuality of its vehicles.

CAPACITY

Coverage: Approximately 80% of vehicles and stations are monitored, representing seven of nine lines. Data are collected continuously. Berlin is considering installing AVL monitoring on the remaining two unmonitored lines.

Technology: Berlin has used Siemens' Vicos AVL technology since 1995.

DATA

Scope: AVL provides arrival times of trains at all stations.

Distribution: Operations personnel can obtain real-time data via computers. These are the basis of "DAISY," the Dynamic Passenger Information System.

Diagnostics: Data are continuously used to compile statistical reports on train punctuality and breakdowns.

Storage: Data are stored for six months.

EVALUATION

Accuracy: Verification of data accuracy is accomplished through the communications computer, which compares each vehicle number to the scheduled number stored in the database. This system allows for exact verification of actual run number versus scheduled run number.

Service Improvements: AVL technology has improved service provision by providing knowledge of train locations and making better information available to passengers.

Hong Kong (MTR) — Metro

OVERVIEW

MTR uses Automatic Train Supervision (ATS) to check train arrival and departure times against timetables.

CAPACITY

Coverage: All vehicles and stations are monitored by ATS. Data for each line are collected daily.

Technology: MTR has used CSEE computer-based ATS since 1985, and upgraded the system in the mid-1990s.

DATA

Distribution: Requests for data are processed through a central analysis group.

Diagnostics: Data are used to produce reports such as car kilometers/failure, train punctuality, revenue car kilometers, and revenue car hours.

Storage: Data are archived indefinitely for analysis and future reference.

EVALUATION

Accuracy: ATS is track-circuit based, and considered very accurate within MTR's system.

Service Improvements: ATS has helped to improve Hong Kong's service provision. Performance reports are produced from the data and are reviewed against performance targets. Responsible managers then take measures to improve performance.

Mexico City, Mexico — Metro

OVERVIEW

Mexico City uses AVL to determine punctuality of vehicles, and staff dispatchers determine reliability.

CAPACITY

Coverage: All vehicles are monitored by AVL. Data for each line are collected daily. 20% of stations are monitored by camera surveillance, and specialized staff monitor all stations.

Technology: In 1993 Mexico City upgraded AVL technology with SISECA (a French company).

DATA

Scope: AVL enables control and pursuit of trains; train storage; terminal maneuvers; interval regulation; time regulation; detection of electric power shorts; signal stops; track apparatus movement control; and personnel-on-tracks indicator. AVL also has limited ability to compensate for late trains.

Diagnostics: Daily and monthly reports are produced from AVL data. Station monitoring staff make daily reports of incidents on tracks.

EVALUATION

Accuracy: AVL is operated in real time, with a precision of seconds.

Service Improvements: AVL has been in operation since the inauguration of the first line, so service improvements are impossible to evaluate. However, upgrades of technology have improved staff usage.

New York, USA (Bus) — Bus

OVERVIEW

Currently New York City Transit (NYC Bus) has dispatchers and Traffic Checkers (a separate monitoring staff) determine reliability/punctuality of buses manually. AVL is being developed, but is not yet in use.

CAPACITY

Coverage: Dispatchers monitor buses at terminals and key intermediate locations. Data are gathered daily by route. Traffic Checkers monitor 2% of all weekday bus trips each calendar quarter for reliability assessments. Reliability assessments are performed on 42 bus routes out of 206 local bus routes and are selected from the entire city. Traffic checkers also conduct point checks at terminals, maximum loading points, etc. Data are gathered by route, division, and system. All bus routes, including express bus routes, conduct traffic checks for passenger loads at least once every three years (every four years for the lightest routes).

DATA

Scope: Current methods provide performance indicators such as En-route On-Time Performance (OTP) and Wait Assessment. Future implementation of AVL will gradually supplement and potentially replace manually based performance indicators, and be conducted alongside continued staff traffic checks.

Distribution: Data are analyzed, grouped into discrete performance-related indicators, and used to generate public quarterly reports and detailed internal reports.

Diagnostics: Traffic checks have identified necessary service and schedule changes.

Storage: Manual assessments are retained for about six years. Analyzed data are archived and retained off-line.

EVALUATION

Accuracy: Service reliability checks have an accuracy of 95% confidence, 5% precision at the system level, and 90% confidence, 5% precision at the line level. Checks for passenger loads and service reliability checks are reviewed by field supervision, and analyzed using crosschecks. There is no statistical significance calculated for passenger load checks on individual routes. Each bus route checked has data collected for two to three days for each schedule.

Service Improvements: Service monitoring allows New York City Transit to take corrective actions, such as schedule revisions or service modifications.

New York, USA (Subway) — Metro

OVERVIEW

Currently, vehicle reliability/punctuality is determined by dispatchers and by manual surveys conducted by Traffic Checkers (a separate monitoring staff). ATS and Communication-Based Train Control (CBTC) are being developed for future use.

CAPACITY

Coverage: Dispatchers monitor all trains departing terminals, and some trains at intermediate locations. Dispatchers gather information daily by route/line. Traffic Checkers monitor 5% of all weekday subway trips each quarter to assess train service reliability. Traffic checks are conducted one or more times a year on all subway routes except very short shuttle routes (24 out of 28 routes).

DATA

Scope: Traffic checks provide data on passenger loads and performance indicators such as En-route Schedule Adherence and Wait Assessment. These methods will be continued in the future, and operate alongside future ATS.

Distribution: Service reliability-based checks are tabulated as route, division, and system-level performance-related indicators that are issued on a quarterly basis. Detailed passenger load reports are distributed internally, as requested.

Diagnostics: Traffic check data are used to generate schedule and service reviews, to identify necessary service and schedule changes (e.g., change in trips, peak trains, running time).

Storage: Manual assessments are retained for about six years; analyzed data are archived and retained off-line.

EVALUATION

Accuracy Service reliability surveys are accurate at 95% confidence, 5% precision at the system level and 90% confidence, 5% at the line level. Service reliability surveys are reviewed by field supervision, and is analyzed using crosschecks. Traffic checks for passenger loads are collected for two to four days for each line and each year; sample sizes are too few to calculate statistical significance.

Service Improvements: By identifying under-performing routes/lines, NYC Subway can take corrective actions such as schedule revisions or service modifications.

São Paulo, Brazil — Metro

OVERVIEW

São Paulo uses ATS and cameras to determine the reliability/punctuality of its trains.

CAPACITY

Coverage: All vehicles and stations are continuously monitored by ATS. Data are gathered by line. All stations and stops are also monitored continuously by camera surveillance. These data are gathered by station.

Technology: For ATS, Line One uses DTL Westinghouse (made in 1960s); Line Three uses 8080 IZ80 (made in 1980s); and Alstom trains use a microprocessor system (made in 1990s). For camera surveillance, Line One uses black and white video by Marconi; Line

Three uses color video by Thomson; and Line Two and the Northern, Western, and Eastern extensions use fixed four-split image by Thomson. São Paulo is developing a prototype system to be implemented in one station. It will include a station console monitoring all areas and signals transmitted via WAN to a PDA. It will allow the station operator to move around the station while maintaining control of other station areas. In the future, all Line Four stations will be fully monitored.

DATA

Scope: ATS currently provides round trip duration and station dwell time data. In the future, black boxes recording trip data will be installed in trains. Cameras currently provide passenger flow control data.

Diagnostics: ATS has identified problems with false occupancy, train stop time, and train irregularities. Camera surveillance has identified problems with platform operation, safe train proximity to the platform, and safe departure.

EVALUATION

Service Improvements: Service monitoring technology has helped aid service in the following areas: dwell time; platform operation; aid to disabled persons; and operational strategies for express trains.

Tokyo, Japan — Metro

OVERVIEW

Tokyo determines the reliability/punctuality of its trains by ATS and AVL from an Integrated Control Center. Heat and vibration sensors also monitor equipment for preventive maintenance (to ensure consistency of service).

CAPACITY

Coverage: All trains are monitored continuously by ATS and AVL, which gather data systemwide. Heat sensors monitor the Tozai line, and vibration sensors are at 15 stations (on all lines).

Technology: ATS and AVL were initially implemented in 1991; additional equipment was installed in 1996. Hitachi, Toshiba, and Mitsubishi are the principal suppliers.

DATA

Scope: Service monitoring technology is part of a service quality data system.

Distribution: Delays are automatically displayed. Other information is sent from the Integrated Control Center to the Head Office, then to the sites. Statistical operations data are distributed within the agency.

Diagnostics: Service monitoring is used on a short-term basis, to detect and resolve problems in a timely manner. Heat and vibration sensors help detect problems for preventive maintenance.

EVALUATION

Accuracy: Tokyo's service monitoring technology is considered very accurate.

Service Improvements: Preventive maintenance and efficient handling of problems are important results of service monitoring.

Athens, Greece (Attiko) — Metro

OVERVIEW

To determine reliability/punctuality of trains, Attiko's Operations Control staff manually record a pre-determined sample of train departures compared to the timetable. ATS is provided, but this does not give train service performance information.

CAPACITY

Coverage: Operations Control staff daily monitor 10% of vehicles and stations (outbound only, for terminal station departures). Samples are taken by line, as there are only two lines in the system. All vehicles, stations, and stops are monitored by ATS.

Technology: Alstom ATS was commissioned in 2000 as an integral part of the train supervisory system. Attiko is considering installing new service monitoring technology, but the type is undetermined. If possible, the system should provide required service information.

DATA

Scope: Future technology is expected to provide car mileage and train lateness at specific timing points (compared to timetable).

Distribution: Service performance data are communicated, processed, analyzed, and presented by manual means.

Diagnostics: ATS and manually gathered data have initially been used to produce reports on average lateness per peak period per line. Later, ATS data will be used to report on headways achieved compared to schedule.

Storage: Data are stored indefinitely.

EVALUATION

Accuracy: Attiko reports some shortcomings of their system. Manual recording is a distraction for staff, especially when busy; and the accuracy of the timed data is insufficient (only to the nearest minute) and its correctness is uncertain. ATS data have accuracy to the nearest second; however, these cannot be processed as required for daily systematic analysis.

Barcelona, Spain — Metro, Bus

OVERVIEW

To determine the reliability/punctuality of its trains, Barcelona uses AVL, RdT (route/track based frequency control system), and two kinds of ATS: Automatic Train Protection (ATP) and Automatic

Train Operation (ATO). Dispatchers also monitor trains when the system is failing.

CAPACITY

Coverage: RdT and AVL continuously monitor all trains and stations. ATP and ATO continuously monitor 60% of vehicles. Data are gathered by line as well as system-wide.

Technology: Barcelona's AVL, ATP, and ATO systems are by different manufacturers. RdT is a custom-made system. Barcelona is considering installing Bombardier ATO and ATO systems in lines One and Three.

DATA

Scope: These systems are integrated with SAP R/3 and INP, systems that inform passengers about waiting time in stations. AVL and RdT supply arrival times at stations and continuous location information.

Distribution: Monitoring and Planning departments can query AVL and RdT information through an intranet. Personnel in the field can obtain real-time RdT, ATP, and ATO data via station displays.

Diagnostics: Data are used to produce reports on trip quality.

Storage: Data are stored four years.

EVALUATION

Service Improvements: Service monitoring has helped service provision through measures such as the calculation of new timetables, number of trains, and capacities.

Boston, USA — Metro, Bus, Trolley

OVERVIEW

Boston's metro and surface lines were discussed together in response to this survey. To determine the reliability/punctuality of its vehicles, Boston uses AVL induction loops on the Green Line LRT and on Red and Orange Lines (south portion). Standard fixed block signaling is used on the Blue Line and Orange Line (north portion). Dispatchers monitor both bus and rail. When long-term patterns or problems evolve, ride-checkers contracted from Central Transportation Planning Staff (CTPS) perform run time recording/adjustments.

CAPACITY

Coverage: All rail vehicles, except the Mattapan Line, are continuously monitored via Operations Control Center's strip map/model board. Buses, trackless trolleys, and Mattapan PCC Trolleys use analog voice radio only. 26 buses feature Clever Device GPS units, but these are currently used only for automated stop announcements. Field supervisors are continuously assigned at rail terminals, key locations, and schools (for supplemental bus trips) systemwide. Separate monitoring staff are only used as required (no more than once a year, and for some lightly used bus routes, once every three to five years). Information supplied by station monitoring and separate monitoring staff is gathered by route; information supplied by dispatchers is gathered by line or branch.

Technology: Boston has 26 buses equipped with Clever Device Talking Bus (Syosset, NY) GPS-based automated PA announcement and dot matrix signs. These are being installed in 95 vintage buses as well as in 418 new buses Boston is planning to purchase. 17 (of 44) buses on the Silver Line (Bus Rapid Transit) will install Intelligent Transportation Systems (ITS) units (Siemens) to provide wayside at-surface-stop real-time data. This system will also feature a strip map monitor at the Bus Operations control center. The nature of the BRT future ITS/communications system on the Transitway tunnel segment is undetermined.

DATA

Scope: AVL provides arrival time and car number; dispatchers collect car number and load factor data; and separate monitoring staff gather detailed on/off stop, unit number, and trip information.

Distribution: To access AVL information, the planning department can request copies of Automatic Vehicle Identification (AVI) checkpoint data, which give the time and car number of vehicles passing cordons. Blue Line car numbers are entered manually. The planning department can obtain copies of dispatchers' field reports upon request, and can perform independent surveys or access CTPS data. Smart Routes is contracted to periodically update Boston's website with service information related to delays and other issues; however, this information is not vehicle-specific.

EVALUATION

Accuracy: Boston estimates 98% accuracy for its AVL system. Sometimes the AVI detector fails to record a car or two, but this is a very minor problem. Staff occasionally spot-check for accuracy.

Service Improvements: Boston's technology allows them to address gaps in their rail service, for example, by turning trains and running express.

Budapest, Hungary (Bus) — Bus

OVERVIEW

In Budapest, AVL, dispatchers, and separate monitoring staff monitor reliability of buses.

CAPACITY

Coverage: 40% of vehicles and stations are monitored by AVL. AVL line data are collected every 30 seconds. Dispatchers monitor 60% of vehicles. Separate monitoring staff monitor random buses and stations daily by line.

Technology: AVL equipment is manufactured by MarKeres and OTE, and has been in use since 1994. Budapest Bus is considering integrating GPS technology with AVL.

DATA

Scope: AVL currently provides arrival and departure times of buses.

Distribution: Data collection and analysis are the responsibility of the planning department.

Diagnostics: Data are used to produce reports on schedule reliance and punctuality. AVL, dispatchers, and separate monitoring staff have all identified problems with driver discipline; AVL and dispatchers have also identified “irregularity”; and AVL and separate monitoring staff have identified obstructions.

Storage: Data are stored for one year.

EVALUATION

Accuracy: AVL equipment can determine vehicles’ location with 50-meter accuracy, every 30 seconds. Information from dispatchers is verified by spot-checking.

Service Improvements: Service monitoring technology has helped Budapest Bus improve service, by using data analysis to increase traffic control efficiency and to improve the customer information system.

Budapest, Hungary (Metro) — Metro

OVERVIEW

In Budapest, dispatchers and a track-based train monitoring system monitor vehicle reliability and punctuality for the Metro.

CAPACITY

Coverage: 100% of vehicles are monitored by the route-based system. 100% of stations are monitored by CCTV and dispatchers. All information is collected daily, by line and division.

Technology: Budapest’s route-based monitoring system is manufactured by Integra Domino, and was installed in 1970. This system features a panoramic board that shows rail engagement.

DATA

Scope: Monitoring technology provides data on density of vehicle and passenger traffic, as well as unusual incidents.

Distribution: Data are disseminated manually via hard-copy reports.

Diagnostics: Data are used to produce reports on schedule compliance, performance, causes of breakdowns, causes of accidents, and other issues of interest. Route-based equipment has also been used to determine load capacity of vehicles and escalators.

Storage: Data are stored for one year.

EVALUATION

Accuracy: Data from technology have 80% accuracy, and are verified by spot-checking.

Service Improvements: Service monitoring technology has helped Budapest Metro improve service by using data to match metro service to passenger demand.

Glasgow, Scotland — Metro

OVERVIEW

Glasgow uses a track-based monitoring system to determine the reliability/punctuality of its trains. From the signaling system event logger, one can select the occupation of a sample track circuit to monitor activity.

CAPACITY

Coverage: All of Glasgow's trains and one of its fifteen stations use this monitoring system. The railway has a single circular route with lines in each direction. Information is continuously gathered for each direction of service.

Technology: The signaling system is by ADtranz (1996).

DATA

Scope: The system provides train arrival times at stations.

Distribution: The Maintenance Engineer extracts data and transfers it to a daily report format. The performance spreadsheet is accessible on the company network.

Diagnostics: Daily reports are made on headway infringements and percentage of scheduled service operated. This is subdivided into peak and non-peak hours. The system has helped to interpret service suspensions.

Storage: Data are stored for 30 days.

EVALUATION

Accuracy: Information provided is considered highly accurate.

Service Improvements: Prior to this technology, performance was measured as "lost mileage" from scheduled service. This manual estimate combined the effects of short delays with prolonged suspensions, and was therefore not a good measure of service impact on customers. The current system provides data that promote a customer-focused view.

Hamburg, Germany — Metro, Bus

OVERVIEW

Hamburg uses ATS on all three of its lines to determine the punctuality/reliability of its trains. Automatic detecting systems are located at both ends of stations, and the central control center displays delay announcements. All lines are also monitored by direct communication between drivers and the central control center.

CAPACITY

Coverage: All vehicles and stations are continuously monitored by ATS. All vehicles and selected stations are monitored by continuous communication between drivers and the control center. Information is gathered by line, and analyzed by station, line, and systemwide.

Technology: Hamburger Hochbahn AG developed the software in-house and several manufacturers supplied the hardware. System features include automatic train detection, timetable supervision, operator dispatching support, intermodal connection support, CCTV in stations, and supervision and remote control of station equipment. U2 and U3 lines were supplied in 1985; U1 line was supplied in 2000.

DATA

Scope: Service monitoring technology is integrated with intermodal connection support (metro/metro, metro/bus) and train announcement platform displays with countdowns. ATS provides arrival and departure times at stations. Future technology should provide a direct data-link to the maintenance department, as well as data on physical vehicle spacing, causes of delays, and technical and operational information. Drivers report departure times from key stations.

Distribution: The operations department and anyone else interested receive monthly reports generated from ATS data by an analysis group, as well as monthly reports generated by the central control center.

Diagnostics: Data are used to produce monthly statistics of station delays, and part of a quarterly report on service quality. ATS has identified quantity and distribution of delays and the effect of low speed sections in cases of track construction work. Driver-to-control-center communication determines quantity and causes of delays.

Storage: Automatically collected data are stored for 15 months, manual notes are stored for three years, and evaluations are stored longer.

EVALUATION

Accuracy: ATS detects service needs in seconds; requests to drivers and announcements are made in minutes. Driver communication of service needs takes a few minutes.

Service Improvements: The swift detection of delays leads to quick intervention by the central control center. Knowing the distribution of delays has led to an improved distribution of operation time reserves. Determining the effects of track construction work has led to better planning of track building sites.

Jersey City, USA (PATH) — Metro

OVERVIEW

To determine the reliability/punctuality of its trains, PATH has supervisory staff manually monitor trains, whose locations are tracked on a tiled display board. Terminal Supervisors and Control Center Staff are responsible for dispatching and separate monitoring staff.

CAPACITY

Coverage: All vehicles and stations are continuously manually monitored. Data are gathered by route, peak period, off-peak period, and 24-hour period.

Technology: Display boards are over 25 years old. PATH is considering installing new technology for communication-based train tracking and automatic train control. The type is to be determined.

DATA

Scope: Manual systems are integrated with fare collection data, passenger counts at stations, and computer-assisted data collection logs. Future technologies will provide vehicle spacing and on-time performance data, as well as automating train identification, station monitoring, and staff dispatching.

Distribution: Information is manually monitored, tracked, and entered into a database program.

Diagnostics: Reports on on-time performance and customer satisfaction are produced from manual data. Security and system performance reports are produced from camera surveillance.

EVALUATION

Accuracy: Accuracy is determined by manual comparisons by supervisors.

Miami, USA — Metro, Bus, Automated Guideway

OVERVIEW

Miami-Dade Transit uses ATS and monitoring staff to limited a limited extent, to determine the reliability and punctuality of their vehicles. AVL is being developed.

CAPACITY

Coverage: ATS is used on a random-sample basis to monitor vehicles by route/run. All stations and stops are monitored by ATS and AVL. Staff monitor only a few stations/stops and a limited number of vehicles.

Technology: The AVL system is manufactured by Harris.

DATA

<u>Scope</u>: Miami-Dade is considering integrating service monitoring systems with Automated Passenger Counters. Current technology provides information on vehicle arrival/departure times.

<u>Distribution</u>: Supervisors monitor ATS mimic boards and record data on randomly selected trips. With AVL, planners will be able to obtain reports from the automated system. Separate monitoring staff are testing hand-held collection devices that can upload into computers and generate reports.

<u>Diagnostics</u>: AVL will generate run time deviation and run time reports.

EVALUATION

<u>Accuracy</u>: ATS has statistical accuracy of 95%. Miami-Dade reports "reasonable" accuracy of staff monitoring.

<u>Service Improvements</u>: Systems have helped improve run time accuracy and therefore service reliability.

Milan, Italy — Metro, Bus

OVERVIEW

Milan uses AVL and camera monitoring to determine the reliability and accuracy of its trains and surface lines. Automatic Train Operation (ATO), a type of ATS, is also used in the metro.

CAPACITY

<u>Coverage</u>: Surface vehicles are continuously monitored by CRC (centralized regulation and control system) AVL, and all trains are monitored by Train Describer AVL. These technologies collect data by line. Cameras continuously monitor all stations' vehicle and passenger loading, and collect data by line and station.

<u>Technology</u>: AVL technology has been in use since 1990. Train Describer (by Thermic Plotter) has been installed with the beginning of each line, and black and white CCTV has been installed with the opening of each station.

DATA

<u>Scope</u>: Surface lines integrate vehicle location, vehicle passenger counting, waiting time, and audiovisual announcement information with service monitoring. In metro lines, ATS and AVL are integrated with each other.

AVL currently provides arrival times, continuous location data, vehicle loads, and travel time. Camera monitoring provides information on platform loads and vehicle loads. ATO manages stopping in stations and terminal reverse maneuvers, as well as distributing information to drivers and station operators on train operation, and automatically slowing speeding trains.

<u>Distribution</u>: Data are distributed by PC telex and fax.

Diagnostics: AVL data are used to generate reports on service punctuality, passengers per time band, and service conformity indices.

Storage: Surface line data have been stored since 1999. Metro line data can be stored from three months to five years, depending on the case.

EVALUATION

Accuracy: AVL monitoring precision is ±50 meters, and verified through printing. Camera accuracy is determined through slow-motion review.

Service Improvements: Service monitoring technology has improved service on surface lines through availability of data. CRC data allow surface schedule planners to optimize resources and diversify routes in response to changes in traffic and demand.

Montréal, Canada — Metro, Bus

OVERVIEW

Montréal uses AVL to determine the reliability/punctuality of its buses. Occasionally staff are dispatched for specific purposes.

CAPACITY

Coverage: AVL continuously monitors 10% (170) of Montreal's vehicles. Information is gathered by stop, direction, line, route, division, and period of day. All bus routes and stops are monitored four times every 10-to-13-week planning period.

Technology: Montréal's AVL is integrated with their automatic passenger counting system (Microtronix treadle mats), using the same. This year they are installing Init infrared sensors for low-floor buses.

DATA

Scope: The Microtronix system uses signposts for vehicle location. The Init system will use GPS for vehicle location. These systems provide vehicle arrival times, continuous location data, and data on platform loads, vehicle loads, and punctuality. AVL systems are integrated with planning data.

Distribution: A query system with preformatted reports is available for different users to access data.

Diagnostics: Reports on on-time performance and load per route-direction are produced for service level planning.

EVALUATION

Accuracy: Yearly audits of Microtronix show 95% accuracy. Init is expected also to have 95% accuracy.

Service Improvements: Manual counts have been used to improve metro service planning, and AVL technology has helped improve bus service planning.

Portland, USA — Light Rail, Bus

OVERVIEW

To determine the reliability/punctuality of its vehicles, Portland uses ATS and AVL.

CAPACITY

Coverage: Nearly 100% of vehicles are continuously monitored by ATS and AVL, although sometimes data are missing. Only timepoints (about one-third of stations) are monitored by ATS. All bus stops are continuously monitored by AVL. Data are collected by stop, trip, time of day, direction, route, and systemwide.

Technology: ATS loops in the trackbed are a Union Switch and Signal SCADA System. AVL is Orbital Sciences GPS-based bus dispatch system with customized data collection technology on board the vehicle.

DATA

Scope: ATS loops in the trackbed report locations and times of vehicles. Data for timepoint stations are stored in a database, and actual times are compared to scheduled times. ATS also measures terminal on-time performance at the beginning and end of the lines. Future Automated Passenger Counting (APC) technology will collect data on passenger loads, boardings, and alightings. Buses' on-board AVL systems track time at all stops on all trips. Leave times are compared to scheduled times at timepoints. AVL also collects data on doors open, dwell time, actual stop location, lift deployment, boardings and alightings (for 60% of vehicles), vehicle operator, and vehicle identification.

Distribution: Data are disseminated through the planning department. Portland is developing an intranet application to query all AVL data and summarize the information.

Diagnostics: Reports on service delivery, on-time performance, run-time analyses, and other indicators, are generated from data. AVL has identified detailed operator-specific information, such as running early and leaving late. AVL and APC can compare load and headway relationships to determine, for example, if bus bunching causes overloads.

Storage: Data are kept permanently.

EVALUATION

Accuracy: There is no official verification study, but ongoing checks show ATS and AVL information to be very accurate. AVL is accurate within zero to ten seconds, depending on the location.

Service Improvements: AVL has helped improve service provision by allowing Portland to rewrite schedules based on real data, investigate customer complaints, and determine from ridership where to add or cut service. Field Personnel also use data to better monitor service on the street (e.g., operators running early and leaving late). There have been many other benefits from the systems.

Prague, Czech Republic (Bus) — Bus

OVERVIEW

Prague Bus has dispatchers monitor bus reliability/punctuality, and is testing GPS and cameras for service monitoring.

CAPACITY

Coverage: Twenty percent of buses (about 200) are currently using GPS, which continuously gathers information. During the trial period, information is collected by line; in the future, data will be collected systemwide. Dispatchers continuously monitor about 60% of buses and about 13% of stops, and gather information by line. Cameras continuously monitor one test terminal, which is responsible for about 5% of all vehicles dispatched (on 17 lines).

Technology: Prague's GPS technology supplier is APEX Prague. Current technology was purchased in 1999. Camera surveillance equipment (1998) is supplied by ELBEX and ELVIJA.

DATA

Scope: Trial uses of GPS compare schedules and timetables to actual service. Dispatchers provide data on arrival times at stops.

Diagnostics: Statistical surveys and related management measures are calculated from information gathered by GPS and staff.

Prague, Czech Republic (Metro) — Metro

OVERVIEW

In Prague, ATS, AVL, dispatchers, and cameras monitor reliability of trains. A switch and signal system monitors system conditions for preventive maintenance.

CAPACITY

Coverage: All vehicles and stations are continuously monitored by ATS, AVL, and switch/signal systems. Staff are dispatched as required by operational situations. This information is collected by line. When the train is not at a station, a dispatcher can monitor any selected train with the cameras, which are located at all metro stations. Camera surveillance is systemwide.

Technology: ATS, AVL, switch/signal systems, and dispatching are part of a hierarchical PC network, UniControls (1998). Camera equipment is DV 380, ELVIJA (1994). Future upgrades of the existing system are anticipated.

DATA

Diagnostics: Data from ATS, AVL, and switch/signal systems are used to create daily operation reports, while analysis is produced on a monthly basis. ATS has identified trains running off schedule.

AVL has identified extended dwell times. Data from dispatchers and cameras are used for operations reports. Dispatchers report on various emergencies, while cameras provide information on passenger frequency, safety, and security issues.

Storage: Data are stored for six years.

EVALUATION

Accuracy: ATS, AVL, and switch/signal systems are 100% accurate. Accuracy of dispatchers' information depends on speed and accuracy of data provided to stations by drivers.

Service Improvements: The benefits of Prague Metro's service monitoring technology include flexible solutions of situations; transfers of staff to critical locations; a higher level of safety; and enhanced operation during social events.

Rio de Janeiro, Brazil — Metro

OVERVIEW

To determine the reliability/punctuality of its trains, Rio de Janeiro uses ATS on Line One and AVL on Line Two.

CAPACITY

Coverage: All trains are monitored by either ATS or AVL (depending on the line). All stations are monitored by ATS, and 26% by AVL. Data are collected daily by line.

DATA

Scope: ATS and AVL provide data on train arrival times at key stations.

Distribution: Data collected through ATS and AVL are processed through the Planning Department.

San Francisco, USA (BART) — Metro

OVERVIEW

BART uses ATS and AVL to determine the punctuality/reliability of its trains. Trains are optically scanned while moving from yard/shop area to mainline track. Each vehicle serial number is identified and entered into the Maintenance and Repair Information System (MARIS) database.

CAPACITY

Coverage: All trains are monitored. The Integrated Control System (ICS) central train control computer monitors all train runs and records arrival and departure times of all trains, as well as door open/close times and interlock traversal times. Train/patron on-time measures are analyzed daily by route/line. Mean-time-between-service-delay measures are analyzed for each sub-fleet of vehicles. All vehicles in service are monitored by real-time radio contact with train operators, who record vehicle malfunctions in the MARIS database, assign technicians for troubleshooting and restoration, and assign incident vehicles to shops for completion of maintenance. Cameras in continuous real-time operation are used primarily for security issues in selected vehicles. Video loop data must be retrieved at the vehicle. Dispatchers gather data by line, to match service levels to demand.

Technology: The ICS-central train control computer system contains several mainframe processors. Reliability and statistical analyses are conducted using SAS and various other SQL applications tools. Reliability Engineering uses various computer data sources and analysis programs to calculate punctuality measures for BART.

DATA

Scope: ICS provides several measures of punctuality. Train-on-Time measures the percentage of daily train runs that arrive at the last station within five minutes of scheduled arrival time. Patron-on-Time measures the percentage of daily passenger trips (origin station to destination station) completed within five minutes of scheduled arrival time at destination. Mean-time-between service delay measures the frequency of vehicle-malfunction-caused delays (five or more minutes delay to one or more trains), expressed in vehicle car-hours.

ICS also displays the real-time location of each train, rail-block occupancy information, route/switch status, and key equipment status. The Customer and Performance Research Department conducts quarterly service quality surveys. Engineering contractors use computer programs and the MARIS database to calculate station equipment availability for daily Operations Performance reports. The Financial Planning Department uses Data Acquisition System to compile daily passenger counts. For one or two weeks per year, staff perform vehicle load counts.

Future Plans: BART is planning to install new software and PC-based planning tools to compile train movement data from ICS into a relational database system, to facilitate analyses using PC-based programming tools.

Distribution: All vehicle operations data, malfunction incident descriptions, and maintenance actions are compiled in MARIS. Reliability Engineering Group calculates punctuality measures, which are compiled into daily/weekly/monthly/quarterly reports. These are distributed to Managers and Supervisors throughout BART, posted on the systemwide internal PC-network bulletin board, and displayed in chart format in BART offices, maintenance shops, and public areas. Procedures are under development to permit daily Web-based distribution of these measures.

Diagnostics: Data are used to analyze causes of delays, develop mitigation strategies and equipment reliability improvement modifications, and enhance on-time performance. Daily reports of train/patron on-time service and causes of delay are combined for weekly and monthly summaries. Engineering contractors conduct special analyses of train delays, including simulation studies, system capacity studies, equipment upgrades, and operational/procedural modifications. Through analysis of train delay events and causes, BART has implemented various improved operational procedures and installed wayside equipment improvements. These include improved training of train operators, to expedite recovery from equipment malfunctions; improved train delay management strategies by central operations staff, to minimize delay impacts during major disruptions; and upgraded vehicle components in Automatic Train Operation, door, propulsion, and friction brake systems, to reduce incidence of malfunctions and delays.

Storage: Data are stored for three years or longer.

EVALUATION

Accuracy: BART's system is approximately 90-95% accurate. It is checked with various independent logs and reports produced by Central Operations staff.

Service Improvements: BART's service monitoring technology has helped them better match service to demand, minimizing passenger complaints and maximizing passenger convenience and comfort. Car hours are reduced with properly sized trains.

Singapore Metro

OVERVIEW

Singapore uses ATS to automate route setting, monitor stations, automate dispatching, and monitor scheduled trains for deviations and track occupation. Monitoring and control can be delegated to station control room staff at each station.

CAPACITY

Coverage: All trains are monitored daily, but only scheduled trains are checked for deviations. All mainline stops are recorded daily. ATS and monitoring staff gather information at the division level.

Technology: Singapore uses a Westinghouse Signal Limited proprietary ATS system, purchased in 1987. They are considering an ATS upgrade to a new platform under Windows NT and WAN/LAN architecture, supplied by Westinghouse Signal Limited.

DATA

Scope: ATS provides arrival/departure times and deviations for analysis. Future technology is expected to provide run information for analysis.

Distribution: Information is shared through the company-wide corporate network. ATS workstations provide for timetable creation, train monitoring and control, maintenance monitoring, and analysis. WAN-based ATS connects all stations in the system and LAN at the control center. ATS also transmits track occupation information from station interlocking to control center. Local station computers control route setting and dispatch.

Diagnostics: ATS has identified system design limitations (regarding operational requirements), equipment malfunctions, and software bugs. Weekly management reports are produced to track signaling performance. Should there be a drop in reliability, causes are studied, and remedial measures are implemented to maintain or improve reliability. Other reports produced from ATS data include monthly signaling system performance reports and ad hoc performance reports.

Storage: Data are stored for three years.

EVALUATION

Accuracy: Currently, deviation limit is set at two minutes; practically, deviations can be set anywhere from zero. Manual observations verify accuracy of information.

Service Improvements: Service monitoring systems are used to expedite fault resolution, which improves system availability.

South Africa — Commuter Rail

OVERVIEW

South Africa uses separate monitoring staff to determine the reliability/punctuality of its trains.

CAPACITY

Coverage: 20% of vehicles are monitored through track/route based monitoring, and 80% are monitored by dispatchers and separate monitoring staff.

DATA

Distribution: Dispatchers, separate monitoring staff, and camera surveillance are used to disseminate collected data.

Sydney, Australia — Commuter Rail

OVERVIEW

Sydney uses Train Location System (AVL) to determine the reliability/punctuality of its trains. Blocksheets from stations, signal boxes, and train controllers are also compiled manually for reports.

CAPACITY

Coverage: The Train Location System continuously monitors the busiest 11% of stations in real time. Data are analyzed by station, monitoring point, and node between stations. All peak services and approximately 98% of off-peak services are monitored manually by staff. These data are collected twice daily and analyzed by train, line, station, and on other levels. (With new technology, these data may be collected continuously). For published reports, staff monitor at the CBD and final destination; this represents 19% of stations.

Technology: The latest version of Train Location System was implemented in September 2001. Manual monitoring by staff has been ongoing since 1979. Sydney is considering implementing a combination of Transponders (1995) used for Train Radio and Train Location System-based signaling.

DATA

Scope: Sydney's service monitoring systems are integrated with train radio and train control data collection systems. Train Location System provides continuous location information in real time. (Future technology would expand the area covered by this system.) Monitoring staff determine arrival times at key stations, causes of delays, and other service disruptions.

Distribution: Requests for information are generally processed through Performance Analysis, a central analysis group. This group also publishes reports on the Internet and internally publishes regular reports.

Diagnostics: Reports on headway and diversion are made from AVL data. Staff data form the basis of reports on service disruption causes, on-time running percentages (by line and train number), cancellations, and minutes late. Trends, total quality management analyses, and other statistical techniques are applied as required. AVL has identified late running trains, and staff techniques have identified various problems and issues. In particular, staff review on-time running percentage and causes of delays, looking for trends. They also review Sydney's poorest performing services.

Storage: Data are stored for ten years.

EVALUATION

Accuracy: Peak accuracy is 100%; for off-peak periods, the system has 98% accuracy Monday to Friday, and 95% accuracy on weekends. This is verified through Train Location System.

Service Improvements: Identification of problems has led to corrective action and implementation of strategies such as timetable changes, staff training, new equipment, and changes to maintenance regimes.

Taipei, Taiwan — Metro

OVERVIEW

Taipei uses ATS on its entire system to determine the reliability/punctuality of its trains.

CAPACITY

Coverage: All trains and stations are monitored by ATS. Data are gathered by line. Data for heavy capacity transit are collected daily, and data for medium capacity transit are collected continuously.

Technology: Taipei uses ATS technology manufactured by Automatic Train Control, ALSTOM Signalling, Inc. (1995), and Matra (Val system, 1986).

DATA

Scope: For heavy capacity transit, service quality and passenger counting data collection systems are integrated with service monitoring. For medium capacity transit, vehicle location data collection is integrated with service monitoring. ATS provides data on arrival/departure times of trains at every station, and compares actual times with scheduled times.

Distribution: Train operation data are collected by Information System, a computer located at the Central Control Room. There, a controller compiles data into a Daily Performance sheet, which is emailed daily to the planning department.

Diagnostics: Data are used to create reports on service levels, including headway, speed, delay, and on-time rate.

Storage: Data are stored for 30 days.

EVALUATION

Accuracy: Accuracy approaches 100%, although methods have not been verified.

Service Improvements: Service monitoring is integrated with passenger counting, which allows Taipei to estimate and adjust the quantity of Automatic Fare Collection equipment, employees, and cars actually needed for stations.

Toronto, Canada (Subway) — Metro

OVERVIEW

Toronto uses ATS and AVL to determine the reliability/punctuality of its trains. ATS data are extracted from IPHC (Intermediate Point Headway Control System). Toronto's AVL system, RNTS (Run Number Tracking System), displays the location and direction of each train, based on track occupancy.

CAPACITY

Coverage: ATS and AVL monitor all vehicles. ATS field units are located at terminals and selected intermediate points; on average, 20% of all station stops are monitored. ATS line data are collected daily. AVL monitors all mainline locations.

Technology: The IPHC (ATS) system was developed by LSKS Signals (1993). The RNTS (AVL) system was developed by Wardrop Engineering, Inc. and Advanced Railway Concepts, Ltd. (1998). Alstom is developing a new system (Central Signal System, CSS) for Toronto, which is expected to replace RNTS and IPHC in 2002. CSS is a computerized train control system. It will control the fixed block signal system and monitor train movements. Workstations in the control center will monitor and control the line. Train dispatching at terminals will be automatic, and automatically adjustable at intermediate points on the line. CSS will gather data continuously.

DATA

Scope: Through ATS, automatic train dispatch and headway adjustment are available at terminals and intermediate selected locations. On the line with Automatic Train Operation, ATS measures the total number of actual trips versus scheduled trips. AVL monitors and displays all trains' location and direction on the mainline. Train controllers manually assign each corresponding train run number to the track section occupied by the train, and the system monitors the movement of the train based on track occupancy. While ATS and AVL currently provide arrival and departure times at selected locations, CSS will provide trains' adherence to schedule, running times, and train identification, in addition to arrival and departure times at all locations.

Distribution: Requests for ATS data must be processed through a central analysis group.

Diagnostics: At selected points throughout the two subway lines, ATS measures Headway Performance Percentage (the percentage of headways less than scheduled headway plus two minutes, compared to total headways). These data are compiled into daily, weekly, and monthly Line Headway Performance Percentage reports. With CSS these reports will be continued, alongside additional management reports on dwell times, partial running times, and running time in excess of scheduled running time.

Storage: ATS data are kept in the system for seven days. Data are then copied to diskettes and maintained for one year. AVL/AVL data are not stored or used for purposes other than initial train location display.

EVALUATION

Accuracy: ATS is estimated to be about 95% accurate. AVL shows the track sections occupied by the train, but not the exact location of the train.

Service Improvements: Subway service reliability measures have been used to analyze and identify problem areas/periods and develop more efficient and realistic schedules and running times. Performance is measured against established benchmarks.

Toronto Canada (Surface Transportation) — Bus, Streetcar

OVERVIEW

Toronto uses AVL, other route-based monitoring, and separate monitoring staff to determine the reliability/punctuality of its buses and streetcars. Toronto's Communications and Information System (CIS, the AVL system) tracks the location of all buses and streetcars in service and measures position against schedule. Using data from CIS, the Route Management System measures the percentage of buses and streetcars within plus/minus three minutes of scheduled headway. In addition to CIS, Route Supervisors are posted at key points on routes and at the bus/streetcar loops of key subway stations.

CAPACITY

Coverage: All buses and streetcars in service are monitored by CIS. CIS data are gathered by route, and Route Management System reports are generated by route and division, as well as systemwide. The Route Management System measures headway adherence on 104 of 135 bus routes (77%) and nine of 11 streetcar routes (82%). Vehicle location is shown on screens in real time.

Technology: CIS consists of vehicle-mounted computers that relay voice and data communications to electronic signal posts installed at intervals along the routes. These signal posts send vehicle location data to roof-mounted antennae. Toronto developed this system, which was implemented in 1991. The Route Management System is an Excel-based application that collects and processes data from CIS. It was also developed in-house and was implemented in 1999. Preliminary work to replace CIS is a capital project for 2002. The replacement system will probably be based on GPS technology, which is faster and more accurate.

DATA

Scope: CIS shows vehicle location relative to wayside signposts located at key locations and periodic intervals along a route. It also incorporates vehicle communication and emergency alarm functions with service monitoring. The Route Management System is a service quality measurement system that obtains data from CIS.

Distribution: Each division's Route Supervisors monitor routes on a real-time basis at CIS consoles. Reports may be generated by CIS; requests for reports by others must be submitted to the Division. The Route Management System generates reports on any combination of routes and time frames. Division Route Management Supervisors, responsible for continuous improvement of headway adherence performance, review these reports. Requests for reports by others must be submitted to the Division.

Diagnostics: From CIS, Toronto generates weekly summary reports at the departmental and divisional level, which show overall headway adherence performance (the percentage of service within plus/minus three minutes of scheduled headway) for bus/streetcar routes. Reports for specific routes are also generated weekly at the divisional level. CIS can indicate patterns of gaps and bunching of service. CIS can also produce reports related to service and system use, including vehicle performance reports (by division, route, run or vehicle), text message logs, individual key push logs, individual running time reports, and headway reports (including variance analysis—by division, route, or run). The Route Management system produces reports on headway adherence, by route, division, or systemwide, for any time period. The Route Management System has identified routes with insufficient running time, delay points on routes due to traffic or passenger congestion, and schedule alterations.

Storage: Live data are stored for one month. Archived CIS data are available on CD. Route Management System data are available from the system's inception in 1997.

EVALUATION

Accuracy: A 1995 CIS study found the system to be accurate within 3% over total route trip distances. Between signposts, the system is dependent on the vehicle's hub odometer, which is accurate within ±6%. The system is capable of tracking a vehicle's position within 100 meters.

Service Improvements: Several improvements have resulted from the use of service monitoring technology. Through a detailed route review and implementation of route management techniques Toronto was able to increase headway adherence performance from 47.3% to 70.8% on one route. On another route, staff addressed the need for additional running time without adding vehicles. Working with the City's Transportation Department staff to implement necessary changes, staff acquired the data necessary to support new or lengthened advanced green traffic signal phases. They also were able to implement a schedule change that added running time and an additional bus to a route under construction, so that there was no degradation in route performance through the construction period.

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Appendix A: Agency Profiles

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APPENDIX A: AGENCY PROFILES

Most information in Appendix A is from survey responses. If indicated (*), information comes from *Jane's Urban Transport Systems*, 2002-2003. Other sources are indicated with footnotes.

Berlin, Germany

BRIEF	Berliner Verkehrsbetriebe (BVG) is the municipal agency that operates the Berlin metro along with buses, tramways, and ferries. The first line of the metro system opened in 1902. Metro stations previously closed when the city was divided, have been reopened and restored.
POPULATION SERVED	3.4 million
PASSENGER JOURNEYS	404.7 million
CAR-KM	134 million (annual)
ROUTE LENGTH KM	151.7
NUMBER OF STATIONS	170
SERVICE FREQUENCY	Peak 3 to 5 min, off-peak 5 to 10 min
HOURS OF OPERATION	04.00 to 01.00*
NEW PROJECTS	A 7-year modernization program is underway that will see the introduction of automated train operation, new trains, new signaling, wide-ranging station improvements, and rolling stock replacement. A number of line extensions are currently underway or have been recently completed.*

Hong Kong (MTR)*

BRIEF	The Hong Kong Mass Transit Railway Corporation (MTR) operates a metro line first opened in 1979. As part of the "Octopus" group of public transportation systems, the Hong Kong MTR has a multimodal integrated smartcard fare system.
POPULATION SERVED	6.8 million (1999)[1]
PASSENGER JOURNEYS	779 million (1999) [2]
CAR-KM	119.2 million (1999)
ROUTE LENGTH KM	74.9 (excluding airport line)[3]

[1] E-mail from Hong Kong MTR, Felix Ng, January 29, 2001.
[2] Ibid.

NUMBER OF STATIONS	43 (excluding airport line)[4]
SERVICE FREQUENCY	Peak 2 min, off-peak 4 min[5]
HOURS OF OPERATION	06.00 to 01.00
NEW PROJECTS	A 13 km Tseung Wan O diversion of the Kwun Tong Line (KTL) was completed in December 2002, and a 1.75-km extension of the KTL terminus from Quarry Bay to North Point was completed in 2001. A 3.5-km single-track shuttle has been approved for the new "Disney Line" between Yam O and a planned Disneyland on Lantau. Complete refurbishment of the rolling stock fleet (759 cars) was completed in 2001, and platform screen doors at 30 stations will be retrofitted between 2003 and 2006. Trials with driverless operation are planned, initially for depot positioning moves.

Mexico City, Mexico

BRIEF	Mexico City's Sistema de Transporte Colectivo opened its first line in 1969. The system now has one steel-wheel line and ten rubber-tire lines.
POPULATION SERVED	18.0 million
PASSENGER JOURNEYS	1,393,149,709 (2000)
CAR-KM	127,003 per car
ROUTE LENGTH KM	200,316
NUMBER OF STATIONS	175
SERVICE FREQUENCY	Peak 115 seconds, off-peak 130 seconds
HOURS OF OPERATION	05.00 to 00.30 weekdays; 06.00 to 00.30 Saturdays; 07.00 to 00.30 Sundays and holidays
NEW PROJECTS	Mexico City is developing a southern extension of Line 8 and an east-west line (No. 12). There is a large rolling stock rehabilitation project in progress on nearly the entire fleet of NM73 cars (Lines A and B, 37 trains and 3 reserve cars). The agency is also purchasing 28 new trains and 18 escalators, and replacing 186 transformers.

[3] Ibid.
[4] Ibid.
[5] Ibid.

New York, USA

BRIEF	New York's metro is operated by MTA New York City Transit (NYC Transit), a division of the Metropolitan Transportation Authority (MTA). The first metro line opened in 1904. The metro operates throughout four of the five boroughs of New York City. NYC Transit also operates most local and express bus service in New York City, and contracts out for paratransit service.
POPULATION SERVED	City 8.0 million, region 16 million
PASSENGER JOURNEYS	1,413 million metro, 762 million bus (2002)[6]
CAR-KM	538 million (2002)
ROUTE LENGTH KM	371
NUMBER OF STATIONS	468
SERVICE FREQUENCY	Peak 2-10 min, off-peak 5-15 min, late night 20 min
HOURS OF OPERATION	24 h
NEW PROJECTS	Since fare discounts and unlimited-ride passes were introduced in 1997/8, ridership has risen sharply (between 1996 and 2002, metro ridership up 27% and bus ridership up 55%). 780 new metro cars are being delivered to replace older cars and increase the fleet size for peak period service increases. The 63rd Street Connection opened in December 2001, providing a 22% increase in capacity between Queens and Manhattan. The Canarsie Line is being retrofitted with fully automated controls. Since 1998, NYC Transit has received delivery of 1695 new buses, including articulated and low-floor models, and some compressed natural gas (CNG) and hybrid-electric buses. Intelligent transportation systems (ITS) are being researched for use in buses and subways.

São Paulo, Brazil

BRIEF	The Companhia do Metropolitano de São Paulo (CMAP) began providing service in 1974. Additional lines began operation in 1979 and 1992. The São Paulo Metro connects with feeder suburban rail, bus and trolleybus services as well as regional rail.
POPULATION SERVED	17.9 million
PASSENGER JOURNEYS	486 million (2000)[7]
CAR-KM	77,226,978

[6] NYC Transit operating statistics, Office of Management and Budget, 2002.
[7] E-mail from São Paulo Metro, Peter Alouche, February 9, 2001.

ROUTE LENGTH KM	49.2
NUMBER OF STATIONS	46
SERVICE FREQUENCY	Peak 1 min 40 s to 2 min 55 s, off-peak 2 min 32 s to 3 min 35 s
HOURS OF OPERATION	04.40 to 01.00
NEW PROJECTS	A section of Line 5 was completed in 2002. Development of a new Line 4 with intelligent stations is planned.

Tokyo, Japan*

BRIEF	The Teito Rapid Transit Authority (TRTA) operates a metro line first opened in 1927. TRTA accounts for 80 percent of metro journeys in Tokyo. High level of interconnectivity with other railways.
POPULATION SERVED	City 8 million, metro area 11.8 million, extended service area 30 million
PASSENGER JOURNEYS	2,082 million (1997)
CAR-KM	236 million (1997)
ROUTE LENGTH KM	177.2
NUMBER OF STATIONS	160
SERVICE FREQUENCY	Peak 1 min 50 s, off-peak 3 to 8 min
HOURS OF OPERATION	05.00 to 00.30
NEW PROJECTS	Continued expansion is planned or under construction for Yurakucho and Hanzomon lines, totaling 26.4 km. TRTA is currently owned by the central and Tokyo metropolitan governments, but plans exist to create a joint stock company by 2003 in line with privatization plans.

Athens, Greece (Attiko Metro)

BRIEF	Attiko Metro began revenue service in 2000. Attiko Metro currently operates two new subway lines serving the city center and the inner suburbs of Athens. A third line (Line 1) is operated by the Athens-Piraeus Electric Railways Company (ISAP).
POPULATION SERVED	3.6 million
PASSENGER JOURNEYS	70 million
CAR-KM	13 million (2001, 6-car trains)

ROUTE LENGTH KM	15 km (revenue service)
NUMBER OF STATIONS	18
SERVICE FREQUENCY	Peak 3 min, off-peak 5 min, quiet times 10 min
HOURS OF OPERATION	05.30 to 24.00
NEW PROJECTS	Four system extensions are under construction totaling another 14 route kilometers. These are expected to open between 2003 and 2005.

Athens, Greece (OASA)

BRIEF	The Athens Area Urban Transport Organisation is the metropolitan authority for planning, financing, operating, and monitoring public transport services in the greater Athens region. It has three subsidiary companies (ETHEL, ILPAP, ISAP) that operate buses, trolley buses, and metro, respectively.
POPULATION SERVED	Approx. 4 million
PASSENGER JOURNEYS	Approx. 600 million unlinked (combined for buses, trolley, and metro)
CAR-KM	Buses 97 million, trolley buses 11.6 million, metro Line 1 (ISAP) 17.8 million, metro Lines 2 and 3 (Attiko) 12 million
ROUTE LENGTH KM	Buses 1000 km, trolley buses 156 km, metro Line 1 25.5 km
NUMBER OF STATIONS	Approx. 7000 bus stops, approx. 650 trolley stops, 23 metro stations (Line 1)
HOURS OF OPERATION	05.00 to 24.00
NEW PROJECTS	New Projects for Athens include application of Telematics in buses and trolley buses, extension of Attiko lines, development of two new tram lines, purchase of new buses and trolley buses, development of interchange stations, and upgrade of Metro Line 1 and its stations.

Barcelona, Spain

BRIEF	Founded in 1926, Barcelona's metro and bus systems have been under municipal control since 1959 and 1960, respectively. In 1980, metro and bus operations were brought under common management through Transports de Barcelona SA, although both continue to operate under separate entities. The metro is currently operated by Ferrocarril Metropolita de Barcelona SA.
POPULATION SERVED	2.2 million (metro)

PASSENGER JOURNEYS	290 million (metro, 25% linked trips)
CAR-KM	60.4 million (metro)
ROUTE LENGTH KM	81.2
NUMBER OF STATIONS	112
SERVICE FREQUENCY	Peak 2 to 4 min, off-peak 5 to 12 min
HOURS OF OPERATION	05.00 to 23.00 Monday-Thursday, 05.00 to 02.00 Friday and Saturday, 06.00 to 24.00 Sunday
NEW PROJECTS	Current projects in Barcelona's system include development of a new Line 9, extensions of other lines, purchase of new trains for Line 5, and handicapped adaptations for all stations.

Boston, USA*

BRIEF	The Boston metro opened in 1897 and is the oldest metro in the United States. The Massachusetts Bay Transportation Authority (MBTA) directly operates bus, trolleybus, metro, and light-rail service; commuter rail and ferry services are operated under contract.
POPULATION SERVED	City 562,000, region 2.6 million
PASSENGER JOURNEYS	Metro 107.6 million, light rail 69 million (1996)
CAR-KM	Metro 36.6 million, light rail 8.9 million, bus 40.9 million, trolley bus 1.2 million (1996)
ROUTE LENGTH KM	Metro/light rail 125, bus 1100, trolley bus 25
NUMBER OF STATIONS	84 (metro/light rail)
SERVICE FREQUENCY	Peak 4.5 min, off-peak 8 min (metro/light rail)
HOURS OF OPERATION	05.00 to 00.30 (metro/light rail)
NEW PROJECTS	Station modernization to improve accessibility and attractiveness. The Haymarket-Science Park section of the Green Line will be relocated underground. A new fleet of articulated trolley buses with partial low flows and dual-mode operation is to be ordered incrementally.

Budapest, Hungary

BRIEF	Full metro service, along with one small-profile line, began running in 1896. Until 1995, Budapest Transport Limited was a municipal public service organization; since 1996, it has operated as a joint-

stock company, with all shares owned by the Budapest Municipality. The company operates five branches—metro, bus, trolley bus, tram, and suburban railways.

POPULATION SERVED	2.5 million
PASSENGER JOURNEYS	1.4 billion unlinked total: metro 323 million, bus 582 million, bus 83 million trolley, tram and cogwheel 374 million, suburban railway 18.4 million
CAR-KM	179 million total: metro 30 million, bus 86 million, trolley bus 6.8 million, tram 37 million, suburban railway 18 million
ROUTE LENGTH KM	1743 total: tram 226.3, trolley bus 66.4, bus 1,180.1, suburban railway 239.5, metro and underground 30.8
NUMBER OF STATIONS	42 metro stations, 681 tram stops, 274 trolley bus stops, 3,460 bus stops, 139 suburban railway stops
SERVICE FREQUENCY	Metro peak approx. 2 min, off-peak 7 to 9 min; other branches peak 5 min, off-peak 7 to 15 min
HOURS OF OPERATION	04.30 to 23.10*
NEW PROJECTS	Budapest has three major projects underway. First is the extension of metro "trade mark" lines, bus, suburban railway, tram and trolley bus lines. Second, the agency is working to establish the Budapest Transport Association (from the Budapest Transport Ltd., VOLÁN Coach Company and Hungarian National Railways to provide easier and cheaper travel for 3.3 million passengers, as well as a single tariff system and integrated rail and parking lot development. Third, the tariff system is to be restructured so that prices will be proportionate to distance traveled; also passes for limited and unlimited journeys will be issued.

Glasgow, Scotland

BRIEF	Glasgow has a small underground railway consisting of a single circular route with 15 stations. The metro first opened in 1896 and was modernized between 1977 and 1980. Tracks are of a non-standard gauge (48 inches) and tunnels are correspondingly small. Trains are three cars long with capacity of 270.
POPULATION SERVED	700,000 (city center)
PASSENGER JOURNEYS	14,500,000 unlinked
ROUTE LENGTH KM	10
NUMBER OF STATIONS	15

SERVICE FREQUENCY	Peak 4 min, off-peak 8 min
HOURS OF OPERATION	06.30 to 23.30
NEW PROJECTS	Current projects include replacement of Automatic Train Operating system, replacement of trainstop (protection) system, and upgrade of CCTV system.

Hamburg, Germany

BRIEF	The first full service metro line was opened in 1912. The metro system, along with the bus system, is operated by the Hamburger Hochbahn AG (HHA), and is a member of the regional public transport authority. A zonal system of ticketing allows for intermodal transfer between vehicles from other operating agencies in the region.
POPULATION SERVED	1.7 million (city); 2.7 million (metropolitan area)
PASSENGER JOURNEYS	173 million linked trips
CAR-KM	65.5 million (4 to 9 car trains)
ROUTE LENGTH KM	101
NUMBER OF STATIONS	89
SERVICE FREQUENCY	Peak 2.5 to 5 min, off-peak 5 to 20 min
HOURS OF OPERATION	04.05 to 01.16*
NEW PROJECTS	LCD displays ("Trainscreen") installed in metro cars provide service information, news, entertainment, and commercials. Operational station staff are expected to be eliminated by 2000, when new technology will permit "self-dispatch" of trains by drivers. *

Jersey City, USA (PATH)*

BRIEF	Full service metro linking New York and New Jersey since 1908. PATH has been operated by the Port Authority of New York and New Jersey since 1962. The heavy rail rapid transit system serves as the primary transit link between Manhattan and New Jersey suburbs and commuter railway lines.
POPULATION SERVED	8.0 million (New York City), 21.5 million in region
PASSENGER JOURNEYS	60.7 million (1996)
ROUTE LENGTH KM	22.2

NUMBER OF STATIONS	11 operational: 6 in New Jersey, 5 in New York (One station was destroyed on 11 September 2001, and another has been closed since then.)
SERVICE FREQUENCY	frequent
HOURS OF OPERATION	24 h

Los Angeles, USA

BRIEF	Metro service (Red Line) opened in 1993, operated by the Los Angeles County Metropolitan Transportation Authority (MTA). MTA also operates 2 light rail lines (Blue and Green Lines) and bus service. Commuter rail service and additional bus service are provided by other agencies.
POPULATION SERVED	8.45 million
PASSENGER JOURNEYS	347 million bus; 29.9 million light rail; 27.9 million heavy rail (2000).
CAR-KM	Light rail 4.7 million miles, heavy rail 3.9 million miles
ROUTE LENGTH KM	Light rail 82.4 directional route miles, heavy rail 31.9 directional route miles
NUMBER OF STATIONS	36 light rail, 16 heavy rail
SERVICE FREQUENCY	Metro peak 5 min, off-peak 10 min; light rail peak 6 min, off-peak 10 to 15 min*
HOURS OF OPERATION	04.43 to 23.32 (metro/light rail)*
NEW PROJECTS	Construction has begun for a 13.1 mile Pasadena extension slated for completion in the mid 00's.

Miami, USA

BRIEF	The Miami-Dade Transit Agency runs bus, metro, people mover (automated guideway), and paratransit services. Metro service began in 1984.
POPULATION SERVED	1.8 million
PASSENGER JOURNEYS	84 million unlinked (system total). 65.8 million bus; 14.1 million heavy rail; 4.2 million automated guideway.
CAR-KM	56.4 million (system total). 44.9 million bus; 9.9 million heavy rail; 1.7 million automated guideway

ROUTE LENGTH KM	2,746.5 total: bus 2,665, heavy rail 67.9, automated guideway 13.7
NUMBER OF STATIONS	21 heavy rail stations, 21 automated guideway stations, 76 bus routes
SERVICE FREQUENCY	Heavy rail peak 6 min, off-peak 15 to 20 min; bus varies depending on route, 15-60 min; automated guideway 90 s
HOURS OF OPERATION	Heavy rail 04.30 to 00.45; automated guideway 05.30 to 00.30; bus 24 hours
NEW PROJECTS	Currently Miami-Dade Transit is constructing an extension to the busway in south Miami-Dade County. They are also completing construction of a one-mile extension to the northernmost station of the elevated heavy rail system.

Milan, Italy

BRIEF	Azienda Trasporti Milanesi (ATM) is responsible for bus, trolleybus, tram, and metro services in the Milan area. The metro first opened in 1964.
POPULATION SERVED	City 1.3 million, region 2.8 million
PASSENGER JOURNEYS	582 million linked
CAR-KM	134.7 million
ROUTE LENGTH KM	1,365.4
NUMBER OF STATIONS	84 metro stations, 6,734 surface stops
SERVICE FREQUENCY	Peak 2 to 2.5 min, off-peak 5 min (metro)*
HOURS OF OPERATION	06.00 to 00.30
NEW PROJECTS	Line extensions are currently underway on metro Lines 2 and 3. Further extensions for Line 3 are also proposed.*

Montreal, Canada*

BRIEF	The rubber-tired Montreal metro first opened in 1966. It has been operated by the Societe de transport de la Communauté urbaine de Montreal (STCUM) since 1970, which took on bus operation in 1980.
POPULATION SERVED	City 1.8 million
PASSENGER JOURNEYS	Metro 197 million, bus 340 million (1997)
CAR-KM	Metro 57.5 million, bus 77.3 million (1997)

ROUTE LENGTH KM	metro 65, bus 3,150
NUMBER OF STATIONS	65 (metro)
SERVICE FREQUENCY	Peak 3 to 5 min, off-peak 7 to 10 min (metro)
HOURS OF OPERATION	05.30 to 01.00
NEW PROJECTS	Two extensions are planned for completion in 2004. Line 2 will extend from Henri-Bourassa across the river into Laval and Line 5 will extend from St. Michael to Pie IX.

Portland, USA*

BRIEF	The Tri-County Metropolitan Transportation District of Oregon (Tri-Met) is a public agency established to replace private agencies in the Portland metropolitan area in 1969. Tri-Met provides bus and light rail services for a service area of 950 km² serving three counties in Oregon and Clark County, Washington.
POPULATION SERVED	513,000 city, 1.8 million metropolitan area
PASSENGER JOURNEYS	66 million (both modes)
CAR-KM	Bus 43 million, light rail 8.8 million
ROUTE LENGTH KM	Bus 1350 (one-way), light rail 61.6
NUMBER OF STATIONS	54 (light rail)
SERVICE FREQUENCY	Peak 7-10 min, off-peak and Saturdays 10 min, evenings and sundays 15 min (light rail)
HOURS OF OPERATION	03.33 to 00.32; 03.33 to 01.32 Friday and Saturday nights
NEW PROJECTS	A September 2004 opening is anticipated for the 9.3 km MAX Yellow Line. Construction began in 2001.

Prague, Czech Republic*

BRIEF	Bus, tramway and metro services are provided by the municipal agency Dopravní podnik hlavního mesta Prahy. Transit trips account for 65 percent of weekday journeys.
POPULATION SERVED	1.2 million
PASSENGER JOURNEYS	Metro/tramway 1,076 million, bus 327 million (1997)
ROUTE LENGTH KM	43.6 (metro)

NUMBER OF STATIONS	43 (metro)
SERVICE FREQUENCY	Peak 1 min 50 s
HOURS OF OPERATION	05.00 to 24.00
NEW PROJECTS	A 6.4-km extension of Line B opened in November 1998. Extension and modernization of Line C is slated to begin soon. A new Line D is also proposed to be built.

Rio de Janeiro, Brazil

BRIEF	Opportrans Concessao Metroviaria S.A. provides public transportation on two metro lines. The service opened in 1979, under state operation, but Opportrans, a private company, has operated the system since April 1998.
POPULATION SERVED	5.8 million, 10.2 metropolitan area*
PASSENGER JOURNEYS	113 million unlinked (including free entrances)
CAR-KM	18,787,360
ROUTE LENGTH KM	34.9
NUMBER OF STATIONS	31
SERVICE FREQUENCY	Line 1 peak 4 min, off-peak 5.5 min; Line 2 peak 4 min, off-peak 7.5 min
HOURS OF OPERATION	06.00 to 23.00
NEW PROJECTS	There are three new lines proposed, including one connecting to the international airport from Barra da Tijuca. The state government is also pursuing an intermodal public transport project in the metropolitan region.*

San Francisco, USA (BART)

BRIEF	The Bay Area Rapid Transit system (BART) is a heavy rail rapid transit system that opened in 1972. It currently consists of five lines serving major destinations in San Francisco, Oakland, and various points in the East Bay. The total vehicle fleet is 669 vehicles. Seating capacity varies from 64 to 72 seats per car, depending on car type and seating configuration.
POPULATION SERVED	Approx. 742,000
PASSENGER JOURNEYS	90,974,498 unlinked

CAR-KM	35,851,269
ROUTE LENGTH KM	115.8
NUMBER OF STATIONS	39
SERVICE FREQUENCY	Peak 5 to 15 min, off-peak 15 min
HOURS OF OPERATION	04.00 to 24.00
NEW PROJECTS	BART is developing an extension to San Francisco International Airport, conducting a "midlife overhaul" of 438 A and B cars, expanding shops and yard, implementing advanced automatic train control (AATC), and conducting a system capacity study to increase future line-haul and station capacity.

Singapore*

BRIEF	The Land Transport Authority is the owner and builder of transport infrastructure in Singapore, including the metro and light rapid transit systems. Operation of the metro is licensed to Singapore MRT (SMRT). The metro opened in 1987 and is currently being expanded.
POPULATION SERVED	2.9 million
PASSENGER JOURNEYS	337 million (1997/98)
ROUTE LENGTH KM	83
NUMBER OF STATIONS	48
SERVICE FREQUENCY	Peak 2 to 6 min, off-peak 6 min
HOURS OF OPERATION	05.16 to 00.47
NEW PROJECTS	Construction of the new North East line is currently in progress, scheduled for completion in 2003. In addition, various other extensions to the system are also planned.

South Africa

BRIEF	The South African Rail Commuter Corporation provides commuter rail service to six metropolitan areas: Cape Town, Johannesburg, Durban, Pretoria, Port Elizabeth, and East London. Specifics of route length, vehicle km, passenger journeys, etc., vary by city. More information is available on the website www.sarcc.co.za.
NEW PROJECTS	SARCC plans to upgrade rolling stock and signaling equipment.

Stockholm, Sweden

BRIEF	AB Storstockholms Lokaltrafik is the public transport authority for the Stockholm region. It provides bus, commuter train, metro, light rail, and local train service.
POPULATION SERVED	1.8 million greater Stockholm
PASSENGER JOURNEYS	626 trips annual, all modes
CAR-KM	Approx. 15 million per day (all modes, passenger service)
ROUTE LENGTH KM	9500 km (all modes)
NUMBER OF STATIONS	228 stations, 10,000 bus stops
SERVICE FREQUENCY	Peak, approx. 5 min, off-peak approx. 10 min
HOURS OF OPERATION	05.00 to 01.00 (metro)*
NEW PROJECTS	Stockholm is currently planning extensions to the light rail network, and purchase of a new commuter train fleet.

Sydney, Australia

BRIEF	CityRail operates suburban, outer suburban, and regional services in Sydney and surrounding areas. The first line in Sydney opened in 1855. Sydney's rail network was built on a radial pattern with routes linking the center of Sydney with country regions.
POPULATION SERVED	Approx. 4 million
PASSENGER JOURNEYS	302.6 million for 200/2001 (including Olympics patronage), 285.7 million (excluding Olympic-related trips). Rail/rail transfers counted as single journey.
CAR-KM	65.7 million (bus)*
ROUTE LENGTH KM	Over 1030 route km, including outer suburban (intercity) and regional lines
NUMBER OF STATIONS	306 stations including 4 privately owned Airport Line Stations; 173 stations in Sydney suburban area
SERVICE FREQUENCY	Peak 4.3 to 14 min, off-peak generally 15 min (Various stopping patterns; not all trains stop at all stations.)
HOURS OF OPERATION	04.30 to 24.00 weekdays, 04.30 to 01.00 weekends
NEW PROJECTS	Sydney is developing a Parramatta Rail Link between Parramatta and Chatswood. The first stage (Epping to Chatswood) should be

completed in 2008. The second stage (Parramatta to Epping) should be completed in 2010.

Taipei, Taiwan

BRIEF
The Taipei Rapid Transit Corporation is a public transport operator, covering all main corridors in the Great Taipei Metropolitan Area including Mucha, Tamshui, Hsintien, Nankang, Panchiao, Chungho, and Yungho. They provide metro service on main lines linking the centers of those towns. The system opened in July of 1994. It has a paid-up capital of NT$7 billion and employs 2,765 people.

POPULATION SERVED
2.65 million (Taipei); 6.15 million (metropolitan area)

PASSENGER JOURNEYS
268.6 million linked trips

CAR-KM
Heavy Capacity Transit 35.4 million; Medium Capacity Transit 6.8 million.

ROUTE LENGTH KM
65.3 km (whole system)

NUMBER OF STATIONS
62 (whole system)

SERVICE FREQUENCY
Heavy Capacity Transit peak 5 to 7 min, off-peak 7 to 10 min; Medium Capacity Transit peak 5 to 7 min, off-peak 4 to 7 min

HOURS OF OPERATION
06.00 to 24.00 (whole system)

NEW PROJECTS
By pooling financial resources from rapid transit, bus, and parking lot operators, TRTC moved the issuance of IC Contactless Cards to create a complete network of public transport with a single card for passengers.

Toronto, Canada*

BRIEF
The Toronto Transit Commission operates bus, metro, tramway and light rail for Toronto in coordination with neighboring systems. Metro service began in 1954.

POPULATION SERVED
2.3 million (metropolitan region)

PASSENGER JOURNEYS
Metro 142.1 million, tram/light rail 40 million, bus 188 million (1996)

CAR-KM
Metro 63.9 million, tram/light rail 10.9 million, bus 93.6 million (1996)

ROUTE LENGTH KM
Metro 56.4, tram/light rail 79.6, bus 2956 (one-way)

NUMBER OF STATIONS
61(metro)

SERVICE FREQUENCY	Metro peak 2.5 min, off-peak 4 to 7 min; tram/light rail peak 3 to 12 min, off-peak 5 to 16.5 min
HOURS OF OPERATION	05.47 to 01.34 (metro)
NEW PROJECTS	Construction of the Sheppard Avenue East extension (6.4 km) is in progress. The City of Toronto has plans to purchase Union station for development as a city center transit interchange for train, bus, metro, and light rail.

Appendix B: Passenger Counting Technology Survey Results

Passenger Counting Technology	Summary of Agency Responses					Berlin, Germany	Hong Kong (MTR)	Mexico City, Mexico	New York City, USA (Bus)	New York City, USA (Subway)
4. Which of the following do you count and how often are they counted?	Respondents	Agencies Counting	Daily	Annually	Occasionally/ As Needed					
Passengers on vehicles	22	21	5	3	5	-	no	as needed	quarterly	quarterly
Passengers entering vehicles	19	17	5	1	4	occasionally	no	as needed	quarterly	-
Passengers exiting vehicles	19	17	5	1	4	occasionally	no	as needed	quarterly	-
Passengers transferring between routes or lines	20	17	1	2	7	occasionally	twice/year	via survey	as needed	as needed
Passengers entering stations	22	21	9	4	1	occasionally	daily	daily	N/A	daily
Passengers exiting stations	21	19	7	5	1	occasionally	daily	daily	N/A	daily
Other	2	2	2	0	0	-	-		-	-

5. What method is used to collect the following data?	Total	Infrared Detection	Ticketed Entries	Manual Staff Counts	Surveys	Berlin, Germany	Hong Kong (MTR)	Mexico City, Mexico	New York City, USA (Bus)	New York City, USA (Subway)
Passengers on vehicles	19	3	4	15	1	-	-	manual counts	manual counts	manual counts
Passengers entering vehicles	20	5	4	12	2	doorway infrared, manual counts	-	manual counts	manual counts, ticketed entries (AFC fareboxes)	-
Passengers exiting vehicles	20	5	3	12	2	doorway infrared, manual counts	-	manual counts	manual counts	-
Passengers transferring between routes or lines	16	0	5	13	3	manual counts	manual counts	O/D survey	manual counts, ticketed entries (AFC fareboxes)	manual counts
Passengers entering stations	22	1	12	11	1	manual counts	ticketed entries (entry gates)	ticketed entries (turnstiles)	N/A	manual counts, ticketed entries (turnstiles)
Passengers exiting stations	20	1	9	11	2	manual counts	exit gate counts	ticketed entries (turnstiles)	N/A	turnstiles
Other	3	0	0	2	1	-	-	-	-	-

6. What percentage of cars have passenger counting devices?	Respondents	High Percentage	Median Percentage	Low Percentage	Berlin, Germany	Hong Kong (MTR)	Mexico City, Mexico	New York City, USA (Bus)	New York City, USA (Subway)
Automated fare sales and collection	9	100%	100%	100%	-	none	100% turnstiles	100% MetroCard fareboxes	100% MetroCard turnstiles
Infra-red counting technology	10	100%		2.6%	6%	none	none	-	-
Treadle mat, floor pad, or plate	5	15%	N/A	15%	-	none	none	-	-
Other	6	25%	N/A	10%	-	none	-	-	-

Appendix B: Passenger Counting Technology Survey Results

Passenger Counting Technology	Summary of Agency Responses				Berlin, Germany	Hong Kong (MTR)	Mexico City, Mexico	New York City, USA (Bus)	New York City, USA (Subway)
7. If the whole system is not equipped with passenger counting technology, is the equipment moved around, or fixed in a certain location?	Respondents	Whole System Equipped	Equipment Moved	Equipment Fixed					
	19	7	3	3	fixed	-	whole system equipped with turnstiles	whole system equipped with MetroCard fareboxes	whole system equipped with MetroCard turnstiles
8. Please describe the type, manufacturer, and year of any counter technology you use.	Respondents	Oldest	Median Year	Newest					
Automated fare sales and collection	10	1980	1986	1990	-	ticket machines: Ascom & Thorn; AFC Gates: CGA, Cubic, ERG, CTS	MONETEL turnstiles 1980, 1990	MetroCard - Cubic	MetroCard - Cubic
Infra-red counting technology	8	1990	2000	2000	Dilax Intelcom GmbH - 2000	N/A	-	-	-
Treadle mat, floor pad, or plate	4	1995	N/A	1995	-	N/A	-	-	-
Other	2	1987	N/A	1987	-	-		-	-
9. How accurate is your passenger counting technology and how do you verify the accuracy of counts?	Respondents	Highest Level of Accuracy	Median Level of Accuracy	Lowest Level of Accuracy					
Automated fare sales and collection	10	100%	100%	99%	-	99%	100%	accuracy high	accuracy high
Infra-red counting technology	7	99%	97%	70%	5% error; manually verified	N/A	-	-	-
Treadle mat, floor pad, or plate	4	N/A	N/A	N/A	-	N/A	-	-	-
Other	8	100%	100%	99%	-		-	manual surveys reviewed by field supervision	manual surveys reviewed by field supervision

Appendix B: Passenger Counting Technology Survey Results

Passenger Counting Technology	Summary of Agency Responses					Berlin, Germany	Hong Kong (MTR)	Mexico City, Mexico	New York City, USA (Bus)	New York City, USA (Subway)
	Respondents	Yes	No							
10. Is your agency considering installing new passenger counting technology?	25	15	10			no	no	yes	yes	yes
11. If you answered yes to 10, please describe the type of technology and the maker and expected implementation date.	Respondents	Infra-red	Smart Card	Other Automatic Devices						
	13	3	4	5		-	-	contactless smart card in development	Pilot for APC system contemplated	centralized ATS monitoring at command center by 2005
12. What other data collection systems are integrated with passenger counting technology?	Respondents	Service Quality/ Punctuality	AVL	None						
	19	3	5	9		none	service quality	none	AVL under development	-
13. What information does or will your technology provide for analysis?	Respondents	Passengers Entering/ Exiting By Station/Stop	Passengers Entering/ Exiting by Time Period	Train Loads	Other					
Automated fare sales and collection	11	4	6	1	7	-	passenger entries by gate; O/D; entry/exit time; train loads; passenger km	station entries; passenger flow (future)	boardings by route, by time of day	boardings by station entrance, time of day; software infers destinations from origin swipes
Infra-red doorway counting technology	8	3	1	1	2	entering/exiting passengers by train and by station	N/A	-	APC (future)	-
Treadle mat, floor pad, or plate	4	0	0	0	0	-	N/A	-	-	-
Other	10	5	3	2	4	-	-	-	-	-

Appendix B: Passenger Counting Technology Survey Results

Passenger Counting Technology	Summary of Agency Responses					Berlin, Germany	Hong Kong (MTR)	Mexico City, Mexico	New York City, USA (Bus)	New York City, USA (Subway)
14. How long are data stored?	Respondents	Longest Storage	Median Storage	Briefest Storage						
	22	20-30 years	5 years	60 days		10 years	archived	at least 5 years	6 years, some archived	6 years, some archived
15. What reports or analysis do you produce or conduct with the information gathered?	Respondents	Ridership	Revenue	OTP	Other					
	21	17	3	7	9	entering & exiting passengers by line, time of day; line loads	ridership reports; passenger journey on-time	ridership, statistics, budget forecasting	update schedules, revise service	update schedules, revise service
16. Do you perform origin/destination analysis with data collected?	Respondents	Perform O/D Analysis	Do Not Perform O/D Analysis							
	21	11	7			yes	yes	no--done through surveys	on occasion	on occasion
If so, approximately how accurate are the data you produce?	Respondents	Highest Accuracy	Median Accuracy	Lowest Accuracy						
	8	99%	95%	70%		-	99%	-	-	-
17. What service problems or issues have you identified through passenger counting technology?*	Respondents	Insufficient Service	Changes in Passenger Demand	OTP Issues	None					
*Several agencies indicated problems with the equipment itself, rather than service problems detected by equipment. See summary of findings for details.	12	5	3	3	3	-	none	-	insufficient service, OTP issues, changes in demand	insufficient service, OTP issues, changes in demand
18. Has passenger counting technology helped to improve metro service provision?	Respondents	Yes	No							
	17	16	1			-	yes	yes	yes	yes
19. If you answered yes to 18, please describe how you have used the technology to improve metro service.	Respondents	Match Service/ Schedules to Demand	Other Goals/ Analyses							
	14	12	4			-	targets are set for passenger journey on-time	match service to demand	match service to demand	match service to demand

Appendix B: Passenger Counting Technology Survey Results

Passenger Counting Technology	Sao Paulo, Brazil	Athens, Greece (Attiko)	Athens, Greece (OASA)	Boston, USA	Budapest, Hungary (Bus)	Budapest, Hungary (Metro)	Glasgow, Scotland	Hamburg, Germany	Los Angeles, USA	Miami, USA
4. Which of the following do you count and how often are they counted?										
Passengers on vehicles	occasionally	twice/month	as needed	every few years	annually	annually	-	daily	daily	daily
Passengers entering vehicles	-	-	as needed	every few years	annually	every 5 years	-	daily	continuously	daily
Passengers exiting vehicles	-	-	as needed	every few years	annually	every 5 years	-	daily	continuously	daily
Passengers transferring between routes or lines	occasionally	annually	annually	every few years	occasionally	no	-	-	every 3 years	daily
Passengers entering stations	yes	daily	annually	every few years	no	every 5 years	continuously	-	annually	daily
Passengers exiting stations	yes	annually	annually	every few years	no	every 5 years	-	-	annually	N/A
Other	-	-	-	-	-	-	-	-	-	-
5. What method is used to collect the following data?										
Passengers on vehicles	manual counts, ticketed entries	-	manual counts, ticketed entries (on trolleys)	manual counts	pneumatic springs estimate number of passengers based on pressure	manual counts	-	-	doorway infrared, manual counts	manual counts
Passengers entering vehicles	ticketed entries, O/D surveys	-	manual counts	manual counts	based on stop time	manual counts	-	doorway infrared	doorway infrared	operators count entries on electronic fareboxes
Passengers exiting vehicles	ticketed entries, O/D surveys	-	manual counts	manual counts	based on stop time	manual counts	-	doorway infrared	doorway infrared	manual counts
Passengers transferring between routes or lines	manual counts, ticketed entries, O/D surveys	-	manual counts	manual counts	manual counts	manual counts	-	-	manual counts	electronic fareboxes, turnstiles
Passengers entering stations	ticketed entries (AFC gates)	AFC ticket validation	manual counts, ticketed entries; thermal devices	manual counts	not counted	manual counts	ticketed entries (entry gates)	-	manual counts	electronic turnstiles
Passengers exiting stations	ticketed entries (AFC gates), O/D surveys	-	manual counts, ticketed entries; thermal devices	manual counts	not counted	manual counts	-	-	manual counts	N/A
Other	-	-	-	manual counts	-	-	-	-	-	-
6. What percentage of cars have passenger counting devices?										
Automated fare sales and collection	-	-	-	none, all manual	-	-	stations only	-	-	-
Infra-red counting technology	-	-	-	none, all manual	-	-	-	2.6%	5%	-
Treadle mat, floor pad, or plate	-	-	-	none, all manual	-	-	-	-	-	-
Other	-	-	thermal in Line 1	-	25%	-	-	-	-	-

Appendix B: Passenger Counting Technology Survey Results

Passenger Counting Technology	Sao Paulo, Brazil	Athens, Greece (Attiko)	Athens, Greece (OASA)	Boston, USA	Budapest, Hungary (Bus)	Budapest, Hungary (Metro)	Glasgow, Scotland	Hamburg, Germany	Los Angeles, USA	Miami, USA
7. If the whole system is not equipped with passenger counting technology, is the equipment moved around, or fixed in a certain location?										
	-	-	-	N/A	fixed	N/A	system equipped	mobile	mobile (fixed on buses, but buses can be re-routed)	whole system equipped
8. Please describe the type, manufacturer, and year of any counter technology you use.										
Automated fare sales and collection	vending machines: Phonecard 1990s; gates: Edmonson 1980s	-	-	N/A	-	-	-	-	-	Cubic & GFI
Infra-red counting technology	-	-	-	N/A	-	-	-	Dilax 2000	UTA	-
Treadle mat, floor pad, or plate	-	-	-	N/A	-	-	-	-	-	-
Other	-	-	-	N/A	Knorr-Bremse, 1982; R&G, 1996	-	Cubic, 1987	-	-	-
9. How accurate is your passenger counting technology and how do you verify the accuracy of counts?										
Automated fare sales and collection	comparison of tickets sold, money collected, & gate count	100%	-	highly accurate	-	-		-	-	quite accurate
Infra-red counting technology	-	N/A	-	highly accurate	-	-		Manual verification. Not yet 95% (goal)	90% for trip level counts, 70% for passenger loads	-
Treadle mat, floor pad, or plate	-	N/A	-	highly accurate	-	-		-	-	-
Other	-	100%	-	highly accurate	5% margin of error	95% accurate; verif. by on-site staff	near 100%; verif. by control counting	-	-	-

Appendix B: Passenger Counting Technology Survey Results

Passenger Counting Technology	Sao Paulo, Brazil	Athens, Greece (Attiko)	Athens, Greece (OASA)	Boston, USA	Budapest, Hungary (Bus)	Budapest, Hungary (Metro)	Glasgow, Scotland	Hamburg, Germany	Los Angeles, USA	Miami, USA
10. Is your agency considering installing new passenger counting technology?	yes	yes	yes	no	no	yes	no	no	yes	yes
11. If you answered yes to 10, please describe the type of technology and the maker and expected implementation date.	smart card fare collection; bid under preparation	undetermined	load measuring devices by Deister; March 2002	-	-	smart card system	-	-	passive infra-red overhead sensors	still deciding
12. What other data collection systems are integrated with passenger counting technology?	none	none	Telematics, including AVL	none	none	-	-	departure time (in seconds)	ATMS integration in future	-
13. What information does or will your technology provide for analysis?										
Automated fare sales and collection	yes	tickets sold & cash collected per hour; more frequent in future	N/A	-		-		-	-	passengers by time, day, fare type; ridership patterns (future)
Infra-red doorway counting technology	no	N/A	N/A	-		-		-	-	
Treadle mat, floor pad, or plate	no	N/A	N/A	-		-		-	-	
Other	O/D studies	-	-	-	ridership by direction, station, and time period	ridership by time, station; loads	ridership by station, system, time period, ticket type	-	-	

Appendix B: Passenger Counting Technology Survey Results

Passenger Counting Technology	Sao Paulo, Brazil	Athens, Greece (Attiko)	Athens, Greece (OASA)	Boston, USA	Budapest, Hungary (Bus)	Budapest, Hungary (Metro)	Glasgow, Scotland	Hamburg, Germany	Los Angeles, USA	Miami, USA
14. How long are data stored?	indefinitely	indefinitely	5 years	-	10 or more years	20-30 years	60 days	indeterminate	no set policy yet	about 10 years
15. What reports or analysis do you produce or conduct with the information gathered?	OTP, ridership	ridership by weekday	ridership by mode	bus: load profiles, trip summaries; rail: ridership by station, line, time period	ridership, seating/standing capacity, schedule analysis, OTP, etc.	service schedules, statistics, annual reports	ridership by station, system, time period, ticket type	revenue, profit distribution, internal reports	segment level running time & passenger loads	bimonthly ridership, quarterly performance, annual reports
16. Do you perform origin/destination analysis with data collected?	yes	no	-	no	yes	yes	no	yes	yes	yes
If so, approximately how accurate are the data you produce?	95% through sampling	-	-	-	20% margin of error	95%	-	-	70%	quite accurate
17. What service problems or issues have you identified through passenger counting technology?* *Several agencies indicated problems with the equipment itself, rather than service problems detected by equipment. See summary of findings for details.	overload points	problems known; used to match service to demand	-	none	-	insufficient service	peak congestion & under-capacity	none	OTP issues	-
18. Has passenger counting technology helped to improve metro service provision?	yes	yes, somewhat	-	N/A, manual	yes	yes	Yes	potentially	yes, in future	-
19. If you answered yes to 18, please describe how you have used the technology to improve metro service.	match schedules and staffing to demand	match service to loading profiles	-	N/A	display of arrival times at stops; match service/ schedules to demand, etc.	match service and scheduling to demand	match service to demand; revise fares to encourage off-peak travel	-	will use for rescheduling; but high margin of error	-

Appendix B: Passenger Counting Technology Survey Results

Passenger Counting Technology	Milan, Italy	Montreal, Canada	Portland, USA	Prague, Czech Republic	Rio de Janeiro, Brazil	San Francisco, USA (BART)	Stockholm, Sweden	Sydney, Australia	Taipei, Taiwan	Toronto, Canada
4. Which of the following do you count and how often are they counted?										
Passengers on vehicles	daily	every 5 weeks	daily	monthly	-	as needed	twice/month	annually	monthly	3 times/year
Passengers entering vehicles	daily	every 5 weeks	daily	yes	-	daily	-	occasionally	N/A	every 1.5 years
Passengers exiting vehicles	daily	every 5 weeks	daily	yes	-	daily	-	occasionally	N/A	every 1.5 years
Passengers transferring between routes or lines	-	-	every 5 years	every 3 years	by survey	occasionally	-	less than annually	N/A	N/A
Passengers entering stations	-	-	1 - 3 years	twice/year	daily	daily	annually	daily	daily	annually
Passengers exiting stations	-	-	1 - 3 years	twice/year	daily	daily	annually	daily	daily	annually
Other	-	-	-	daily	-	-	-	-	daily	-
5. What method is used to collect the following data?										
Passengers on vehicles	manual counts	treadle mats	doorway infrared	manual counts, surveys, infrared at turnstiles	ticketed entries (AFC)	manual counts, ticketed entries (automatic ticket counter)	manual counts, ATR (photo cells)	manual counts	-	manual counts
Passengers entering vehicles	infrared at entry gates, photo cells	treadle mats	doorway infrared	manual counts, surveys	ticketed entries (AFC)	manual counts, ticketed entries	manual counts, ATR (photo cells)	manual counts	-	manual counts
Passengers exiting vehicles	infrared at entry gates, photo cells	treadle mats	doorway infrared	manual counts, surveys	ticketed entries (AFC)	manual counts, ticketed entries	manual counts, ATR (photo cells)	manual counts	-	manual counts
Passengers transferring between routes or lines	-	-	-	manual counts, surveys	ticketed entries (AFC)	manual counts, ticketed entries	-	manual counts	-	-
Passengers entering stations	-	-	manual counts	manual counts, surveys, infrared	ticketed entries (AFC)	electronic ticket counter	manual counts	manual counts, ticketed entries (AFC)	ticketed entries (AFC)	manual counts
Passengers exiting stations	-	-	manual counts	manual counts, surveys, infrared	ticketed entries (AFC)	manual counts, ticketed entries	manual counts	manual counts, ticketed entries (AFC)	ticketed entries (AFC)	manual counts
Other	-	-	-	manual counts, surveys	-	-	-	-	O/D table	-
6. What percentage of cars have passenger counting devices?										
Automated fare sales and collection	-	-	-	not on buses	stations: 100% automatic entry gates	-		N/A	-	-
Infra-red counting technology	100%	-	65%	metro: 100% for entering/ exiting	-	-		N/A	-	-
Treadle mat, floor pad, or plate	-	15%	-	not on buses	-	-		N/A	-	-
Other	-	-	-	not on buses	-	-	ATR: about 10%	N/A	-	-

Appendix B: Passenger Counting Technology Survey Results

Passenger Counting Technology	Milan, Italy	Montreal, Canada	Portland, USA	Prague, Czech Republic	Rio de Janeiro, Brazil	San Francisco, USA (BART)	Stockholm, Sweden	Sydney, Australia	Taipei, Taiwan	Toronto, Canada
7. If the whole system is not equipped with passenger counting technology, is the equipment moved around, or fixed in a certain location?										
	-	fixed but distributed to meet sampling requirements	mobile	metro system equipped	-	system equipped	-	fixed	N/A	APC in test phase
8. Please describe the type, manufacturer, and year of any counter technology you use.										
Automated fare sales and collection	-	-	-	-	-	fare gates by Cubic, IBM; various years	-	Cubic	AFC: Alcatel since 1986; OMRON since 1998	-
Infra-red counting technology	1990	still developing: Init	Red Pine	-	-	none	-	-	-	-
Treadle mat, floor pad, or plate	-	Microtonix treadle mat 1995	-	-	-	none	-	-	-	-
Other	-	-	-	-	-	-	-	-	-	-
9. How accurate is your passenger counting technology and how do you verify the accuracy of counts?										
Automated fare sales and collection	-	-	-	-	-	-	-	fairly accurate; compare to manual count	~100%; verify by simulating revenue service	-
Infra-red counting technology	-	-	98.8%	-	-	-	-	-	-	-
Treadle mat, floor pad, or plate	-	95% - manual verification	-	-	-	-	-	-	-	-
Other	-	-	-	metro: 89% - traffic survey	-	manual counts compared to computer model	-	-	-	-

Appendix B: Passenger Counting Technology Survey Results

Passenger Counting Technology	Milan, Italy	Montreal, Canada	Portland, USA	Prague, Czech Republic	Rio de Janeiro, Brazil	San Francisco, USA (BART)	Stockholm, Sweden	Sydney, Australia	Taipei, Taiwan	Toronto, Canada
10. Is your agency considering installing new passenger counting technology?	no	yes	yes	yes	no	no	yes	yes	no	yes
11. If you answered yes to 10, please describe the type of technology and the maker and expected implementation date.	-	commission infrared system by April 2003	Red Pine APC; ongoing implementation	pneumatic load measuring devices; JKZ Olomouc; 2002	-	-	-	smart card system expected by 2005	-	infrared in test phase in 2002. Maker undetermined.
12. What other data collection systems are integrated with passenger counting technology?	AVL, passenger announcements, wait times	GPS	AVL	vehicle speed, OTP, fuel usage, service quality	-	none	traffic control and maintenance	-	none	none
13. What information does or will your technology provide for analysis?										
Automated fare sales and collection	-	-	-	-	-	passengers entering/exiting by time & station		tickets sold, journeys, farebox revenue, entries, exits	journeys by ticket type, entries, exits by station, time	-
Infra-red doorway counting technology	passengers entering, exiting, & on-board by line, stop, & time period	-	passenger on-off, loads by stop and trip level	-	-	-		-	-	-
Treadle mat, floor pad, or plate	-	-	-	-	-	-		-	-	-
Other	-	-	-	OTP, ridership by stop (future)	-	computer model estimates passenger on-off times, loads by station & time	vehicle km, traveling speed, average speed	future: passenger movement on and off (smart card)	-	-

Appendix B: Passenger Counting Technology Survey Results

Passenger Counting Technology	Milan, Italy	Montreal, Canada	Portland, USA	Prague, Czech Republic	Rio de Janeiro, Brazil	San Francisco, USA (BART)	Stockholm, Sweden	Sydney, Australia	Taipei, Taiwan	Toronto, Canada
14. How long are data stored?	since 1999	2 years	6 months to 2+ years	1 - 5 years	-	few years	-	1 year (detailed); archived (summary)	years	10+ years
15. What reports or analysis do you produce or conduct with the information gathered?	ridership by line, time period, schedule type	service planning, OTP, ridership	ridership by line, station, time period, mode, system	project preparation, train flowchart	-	daily passenger unlinked trips, passenger load analysis, special studies	-	trips; revenue by station, month, ticket type	journeys by ticket type, entries, exits by station, time	ridership by time pd; OTP; headways
16. Do you perform origin/destination analysis with data collected?	-	no	no	metro: yes	-	yes	-	yes	yes	no
If so, approximately how accurate are the data you produce?	-	-	-	89%	-	generally accurate	-	-	about 100%	-
17. What service problems or issues have you identified through passenger counting technology?*	-	-	-	metro: passenger flow changes	-	-	-	-	-	-
18. Has passenger counting technology helped to improve metro service provision?	-	no	yes	yes	-	yes	-	yes	yes	yes
19. If you answered yes to 18, please describe how you have used the technology to improve metro service.	-	-	match service to demand; fewer capacity issues	match service to demand	-	special studies, e.g., bicycles, train loading, fire egress	-	-	match service to demand; expand AFC and staffing	match service to demand

*Several agencies indicated problems with the equipment itself, rather than service problems detected by equipment. See summary of findings for details.

Appendix C: Service Monitoring Technology Survey Results

Service Monitoring Technology	**Summary of Agency Responses**		**Berlin, Germany**	**Hong Kong (MTR)**	**Mexico City, Mexico**	**New York City, USA (Bus)**	**New York City, USA (Subway)**	**Sao Paulo, Brazil**
4. How do you determine the reliability/punctuality of your vehicles?	Number of Respondents	Respondents Using This Method						
Automatic Train Supervision	20	15	-	yes	-	no	developing	yes
Automatic Vehicle Location	22	17	yes	no	yes	developing	-	-
Other systemwide track or route based monitoring	11	4	-	no	-	-	-	-
Manually by dispatching staff	13	12	-	-	yes	yes	yes	-
Manually by separate monitoring staff	14	11	-	-	-	yes	yes	-
Camera surveillance	10	4	-	no	-	-	-	yes
Other	4	3	-	-	-	-	-	-

5. How is technology used to disseminate collected data? (e.g., querying through an intranet, processing through a central analysis group)	Number of Respondents	Intranet	By Central Group/Dept	Manually	Berlin, Germany	Hong Kong (MTR)	Mexico City, Mexico	New York City, USA (Bus)	New York City, USA (Subway)	Sao Paulo, Brazil
Automatic Train Supervision	13	4	9	2	-	central group	-	N/A	-	-
Automatic Vehicle Location	14	7	4	0	intranet in real time	N/A	-	-	-	-
Other systemwide track or route based monitoring	8	3	0	3	-	N/A	-	-	-	-
Manually by dispatching staff	8	1	1	6	-	-	-	manually	manually	-
Manually by separate monitoring staff	10	1	3	5	-	-	manually	manually, customer website	manually, customer website	-
Camera surveillance	3	0	0	0	-	N/A	-	-	-	-
Other	3	0	2	0	-	-	-	-	-	-

Appendix C: Service Monitoring Technology Survey Results

Service Monitoring Technology	Summary of Agency Responses				Berlin, Germany	Hong Kong (MTR)	Mexico City, Mexico	New York City, USA (Bus)	New York City, USA (Subway)	Sao Paulo, Brazil
6. What percentage of vehicles are monitored?	Number of Respondents	Maximum Percent Monitored	Minimum Percent Monitored	Median Percent Monitored						
Automatic Train Supervision	17	100%	60%	100%	-	100%	-	N/A	eventually 100%	100%
Automatic Vehicle Location	19	100%	10%	100%	80%	N/A	100%	eventually 100%	-	
Other systemwide track or route based monitoring	7	100%	77%	100%	-	N/A	-	-	-	-
Manually by dispatching staff	10	100%	60%	80%	-	-	-	at terminals and key intermediate stops, in fixed or variable posts	100% at terminals, some in between	-
Manually by separate monitoring staff	9	100%	2%	80%	-	-	-	2% weekday	5% weekday	-
Camera surveillance	6	100%	5%	N/A	-	N/A	-	-	-	-
Other	5	100%	100%	100%	-	-	-	-	-	-

Service Monitoring Technology	Number of Respondents	Maximum Percent Monitored	Minimum Percent Monitored	Median Percent Monitored	Berlin, Germany	Hong Kong (MTR)	Mexico City, Mexico	New York City, USA (Bus)	New York City, USA (Subway)	Sao Paulo, Brazil
7. What percentage of stations or stops are monitored?										
Automatic Train Supervision	16	100%	20%	100%	-	100%	-	N/A	not yet in place	100%
Automatic Vehicle Location	15	100%	11%	100%	80%	N/A	-	not yet in place	-	-
Other systemwide track or route based monitoring	5	100%	7%	100%	-	N/A	-	-	-	-
Manually by dispatching staff	10	100%	13%	100%	-	-	-	at terminals and key intermediate stops	100% at terminals, some in between	-
Manually by separate monitoring staff	10	100%	10%	60%	-	-	100%	max load points, terminals, all stops on checked routes	max load points, terminals, all stations on checked routes	-
Camera surveillance	8	100%	100%	100%	-	N/A	-	-	-	100%
Other	5	100%	100%	100%	-	N/A	-	-	-	-

Appendix C: Service Monitoring Technology Survey Results

Service Monitoring Technology	Summary of Agency Responses				Berlin, Germany	Hong Kong (MTR)	Mexico City, Mexico	New York City, USA (Bus)	New York City, USA (Subway)	Sao Paulo, Brazil
8. Please describe the type, manufacturer and year of any service monitoring technology you use.	Number of Respondents	Earliest Year	Median Year	Latest Year						
Automatic Train Supervision	17	1965	1993	2000	-	CSEE 1985; updated 1993	-	N/A	not yet in place	Westinghouse, CMW, Alstom 1960s-1990s
Automatic Vehicle Location	18	1990	1998	2001	VICOS by Siemens, since 1995	N/A	modernized by SISECA, 1993	not yet in place	-	-
Other systemwide track or route based monitoring	6	1970	1996	1998	-	N/A	-	-	-	-
Manually by dispatching staff	4	1998	N/A	1998	-	-	-	-	-	-
Manually by separate monitoring staff	5	1979	N/A	1979	-	-	-	manual Traffic Checks	manual Traffic Checks	-
Camera surveillance	6	1975	1994	1998	-	N/A	-	-	-	Marconi, Thomson 1970s-1990s
Other	3	N/A	N/A	N/A	-	N/A	-	-	-	-

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Service Monitoring Technology	Summary of Agency Responses				Berlin, Germany	Hong Kong (MTR)	Mexico City, Mexico	New York City, USA (Bus)	New York City, USA (Subway)	Sao Paulo, Brazil
9. How accurate is your service monitoring technology and how do you verify information gathered?	Number of Respondents	Computer Verified	Manually Verified	Not Verified						
Automatic Train Supervision	13	1	3	2	-	accurate	-	-	-	-
Automatic Vehicle Location	15	1	1	1	verify by computer	N/A	precise	-	-	-
Other systemwide track or route based monitoring	5	0	1	0	-	N/A	-	-	-	-
Manually by dispatching staff	5	0	2	0	-	-	-	-	-	-
Manually by separate monitoring staff	8	1	2	0	-	-	-	95% confidence, 5% precision at system level; verif. manually	95% confidence, 5% precision at system level; verif. manually	-
Camera surveillance	4	0	0	0	-	N/A	-	-	-	-
Other	2	0	0	0	-	-	-	-	-	-
10. Is your agency considering installing new service monitoring technology?	Number of Respondents	Considering New Technology	Not Considering New Tech.							
	27	18	9		yes	no	no	yes	yes	yes
11. If you answered yes to 10, please describe the type of technology and the manufacturer.	Number of Respondents	Considering ATS	Considering AVL	Considering Other Technology						
	19	6	7	3	expand AVL (VICOS) to remaining two lines	N/A	N/A	AVL	ATS	station monitoring consoles
12. What other data collection systems are integrated with service monitoring technology?	Number of Respondents	Customer Information	Passenger Counting	None						
	20	3	3	5	-	none	none	-	-	-

Appendix C: Service Monitoring Technology Survey Results

Service Monitoring Technology	Summary of Agency Responses				Berlin, Germany	Hong Kong (MTR)	Mexico City, Mexico	New York City, USA (Bus)	New York City, USA (Subway)	Sao Paulo, Brazil
13. What information does or will your technology provide for analysis?	Number of Respondents	Times, OTP	Continuous Location Information	Vehicle/ Platform Loads						
Current Technology										
Automatic Train Supervision	12	9	1	0	-	arrival/ departure times	-	N/A	-	trip duration, station dwell times
Automatic Vehicle Location	18	11	3	3	arrival times at all stations	N/A	headways, terminal maneuvers, signaling, times, etc.		-	-
Other systemwide track or route based monitoring	7	2	1	1	-	N/A	-	-	-	-
Manually by dispatching staff	5	1	0	2	-	-	-	-	-	-
Manually by separate monitoring staff	6	3	0	1	-	-	-	OTP, wait times	OTP, wait times	-
Camera surveillance	5	0	0	2	-	N/A	-	-	-	passenger flow
Other	2	1	0	0	-	-	-	-	-	-
Future Technology										
Automatic Train Supervision	13	5	0	1	-	N/A	-	N/A	automate indicators	record trip data
Automatic Vehicle Location	13	5	3	1	-	N/A	-	automate indicators	-	-
Other systemwide track or route based monitoring	5	1	1	0	-	N/A	-	-	-	-
Manually by dispatching staff	4	0	1	1	-	N/A	-	-	-	-
Manually by separate monitoring staff	5	2	0	0	-	N/A	-	OTP, wait times	OTP, wait times	-
Camera surveillance	5	0	0	0	-	N/A	-	-	-	full control
Other	1	0	0	0	-	-	-	-	-	-

Service Monitoring Technology	Summary of Agency Responses				Berlin, Germany	Hong Kong (MTR)	Mexico City, Mexico	New York City, USA (Bus)	New York City, USA (Subway)	Sao Paulo, Brazil
14. How often do you gather information?	Number of Respondents	Continuously Gathered	Gathered Daily	Other Gathering Frequency						
Current Method										
Automatic Train Supervision	14	8	5	0	-	daily	-	N/A	-	continuously
Automatic Vehicle Location	19	13	2	1	continuously	N/A	daily	-	-	-
Other systemwide track or route based monitoring	7	2	1	1	-	N/A	-	-	-	-
Manually by dispatching staff	9	4	3	1	-	-	-	daily	daily	-
Manually by separate monitoring staff	8	1	4	2	-	-	-	daily	daily	-
Camera surveillance	6	3	0	0	-	N/A	-	-	-	continuously
Other	2	2	0	0	-	-	-	-	-	-
Future Method										
Automatic Train Supervision	12	8	1	0	-	N/A	-	N/A	not yet in place	continuously
Automatic Vehicle Location	11	8	0	0	-	N/A	-	not yet in place	-	-
Other systemwide track or route based monitoring	5	2	0	0	-	N/A	-	-	-	-
Manually by dispatching staff	8	3	2	1	-	N/A	-	daily	daily	-
Manually by separate monitoring staff	6	2	2	0	-	N/A	-	daily	daily	-
Camera surveillance	5	2	0	0	-	N/A	-	-	-	continuously
Other	2	2	0	0	-	-	-	-	-	-
15. At what level do you gather and analyze information?	Number of Respondents	By Line	By Route	Systemwide						
Automatic Train Supervision	16	9	2	5	-	line	-	N/A	not yet in place	line
Automatic Vehicle Location	18	10	3	2	line	N/A	line	not yet in place	-	-
Other systemwide track or route based monitoring	7	2	2	2	-	N/A	-	-	-	-
Manually by dispatching staff	9	6	3	1	-	-	-	route	line, route	-
Manually by separate monitoring staff	8	4	4	1	-	-	-	route, division, system	station, line, route	-
Camera surveillance	5	1	0	1	-	N/A	-	-	-	station
Other	2	1	0	0	-	-	-	-	-	-

Appendix C: Service Monitoring Technology Survey Results

Service Monitoring Technology	Summary of Agency Responses				Berlin, Germany	Hong Kong (MTR)	Mexico City, Mexico	New York City, USA (Bus)	New York City, USA (Subway)	Sao Paulo, Brazil
16. How long is data stored?	Number of Respondents	Longest Storage	Briefest Storage	Median Storage						
	22	Permanently archived	1 week	1 year	6 months	archived	-	6 years; some archived	6 years; some archived	-
17. What reports or analysis do you produce or do you expect to produce with the information gathered?	Number of Respondents	OTP	Headway	Other						
Automatic Train Supervision	13	7	3	7	-	revenue, car km/failure, OTP, etc.	-	-	not yet in place	-
Automatic Vehicle Location	18	7	3	6	OTP, breakdown data	N/A	service quality	-	-	-
Other systemwide track or route based monitoring	7	1	2	2	-	N/A	-	-	-	-
Manually by dispatching staff	7	2	0	3	-	-	-	-	-	-
Manually by separate monitoring staff	7	5	0	3	-	-	-	publicly released quarterly reports; special internal reports	publicly released quarterly reports; special internal reports	-
Camera surveillance	4	0	0	1	-	N/A	-	-	-	-
Other	3	1	0	0	-	-	-	-	-	-

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Service Monitoring Technology	Summary of Agency Responses				Berlin, Germany	Hong Kong (MTR)	Mexico City, Mexico	New York City, USA (Bus)	New York City, USA (Subway)	Sao Paulo, Brazil
18. What problems or issues have you identified as a result of information gathered through service monitoring technology?*	Number of Respondents	Delays & Service Issues	Equipment Issues	Other						
Automatic Train Supervision	8	5	2	4	-	none	-	-	-	false occupancy, OTP issues
Automatic Vehicle Location	12	8	1	3	delays, equipment problems	N/A	limitations for delay mitigation	-	-	-
Other systemwide track or route based monitoring	6	2	0	1	-	N/A	-	-	-	-
Manually by dispatching staff	4	1	0	3	-	-	-	-	-	-
Manually by separate monitoring staff	6	3	0	3	-	-	-	underperforming routes	underperforming routes	-
Camera surveillance	3	1	0	2	-	N/A	-	-	-	passenger safety, platform operation
Other	3	2	2	0	-	-	-	-	-	-

*Several respondents reported problems with the technology itself. Please see individual responses.

	Number of Respondents	Yes	No		Berlin, Germany	Hong Kong (MTR)	Mexico City, Mexico	New York City, USA (Bus)	New York City, USA (Subway)	Sao Paulo, Brazil
19. Has service monitoring technology helped to improve service provision?	24	22	2		yes	yes	no--in use from beginning	yes	yes	yes

	Number of Respondents	Service/ Schedule Adjustment	Delay/ Problem Resolution	Other	Berlin, Germany	Hong Kong (MTR)	Mexico City, Mexico	New York City, USA (Bus)	New York City, USA (Subway)	Sao Paulo, Brazil
20. If you answered yes to 19, describe how you have used the technology to improve metro service?	22	14	9	14	improved passenger information	set service/ performance goals	-	schedule/ service revisions	schedule/ service revisions	operational strategies, stop times, disabled assistance, etc.

Appendix C: Service Monitoring Technology Survey Results

Service Monitoring Technology	Tokyo, Japan	Athens, Greece (Attiko)	Barcelona, Spain	Boston, USA	Budapest, Hungary (Bus)	Budapest, Hungary (Metro)	Glasgow, Scotland	Hamburg, Germany
4. How do you determine the reliability/punctuality of your vehicles?								
Automatic Train Supervision	yes	yes	yes	-	no	-	-	yes
Automatic Vehicle Location	yes	-	yes	yes	yes	-	-	-
Other systemwide track or route based monitoring	-	-	yes	not in use	no	yes	yes	-
Manually by dispatching staff	-	-	as needed	yes	yes	yes	-	-
Manually by separate monitoring staff	-	yes	no	yes	yes	-	-	-
Camera surveillance	-	-	no	-	no	-	-	-
Other	yes	-	-	-	no	-	-	drivers
5. How is technology used to disseminate collected data? (e.g., querying through an intranet, processing through a central analysis group)								
Automatic Train Supervision	central group, displays	-	displays	-	-	-		central analysis group
Automatic Vehicle Location	-	-	intranet	planning dept. may request	-	-	-	-
Other systemwide track or route based monitoring	-	-	intranet, displays	-	-	manually	manually, intranet	-
Manually by dispatching staff	-	-	-	planning dept. may request	-	manually	-	-
Manually by separate monitoring staff	-	manually	-	planning dept. may request	-	-	-	-
Camera surveillance	-	-	-	-	-	-	-	-
Other	-	-	-	customer website	via planning department	-	-	control center

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Service Monitoring Technology	**Tokyo, Japan**	**Athens, Greece (Attiko)**	**Barcelona, Spain**	**Boston, USA**	**Budapest, Hungary (Bus)**	**Budapest, Hungary (Metro)**	**Glasgow, Scotland**	**Hamburg, Germany**
6. What percentage of vehicles are monitored?								
Automatic Train Supervision	100%	100%	60%	-	-	-	-	100%
Automatic Vehicle Location	100%	-	100%	rail 100% with strip map/model board, ~3% of buses with GPS	40%	-	-	-
Other systemwide track or route based monitoring	-	-	100%	-	-	100%	100%	-
Manually by dispatching staff	-	-	none	-	60%	-	-	-
Manually by separate monitoring staff	-	10% sample	none	-	varies	-	-	-
Camera surveillance	-	-	none	-	-	-	-	-
Other	vibration sensors 100%; heat sensors on 1 line	-	none	analog voice radio on buses and trolleys	-	-	-	100%
7. What percentage of stations or stops are monitored?								
Automatic Train Supervision	-	100%	60%	-	-	-	-	100%
Automatic Vehicle Location	-	-	100%	-	40%	-	-	-
Other systemwide track or route based monitoring	-	-	100%	-	-	100%	7% (1 station)	-
Manually by dispatching staff	-	-	none	terminals, key locations, schools	-	100%	-	-
Manually by separate monitoring staff	-	10% terminal outbound departures	none	-	varies	-	-	-
Camera surveillance	-	-	none	-	-	-	-	-
Other	15 key stations	-	none	-	-	-	-	key stations

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Service Monitoring Technology	Tokyo, Japan	Athens, Greece (Attiko)	Barcelona, Spain	Boston, USA	Budapest, Hungary (Bus)	Budapest, Hungary (Metro)	Glasgow, Scotland	Hamburg, Germany
8. Please describe the type, manufacturer and year of any service monitoring technology you use.								
Automatic Train Supervision	Hitachi, Toshiba, Mitsubishi 1996	Alstom, 2000	various	-	-	-	-	Hamburger Hochbahn AG software, 1985; various hardware
Automatic Vehicle Location	Hitachi, Toshiba, Mitsubishi 1996	-	various	Clever Device GPS	MarKeres, OTE; 1994 and after	-	-	-
Other systemwide track or route based monitoring	-	-	in-house	-	-	Integra Domino License, 1970	Adtranz, 1996	-
Manually by dispatching staff	-	-	-	-	VHF, OTE; 1998 and after	-	-	-
Manually by separate monitoring staff	-	-	-	-	-	-	-	-
Camera surveillance	-	-	-	-	-	-	-	-
Other	-	-	-	Siemens ITS	-	-	-	-

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Service Monitoring Technology	Tokyo, Japan	Athens, Greece (Attiko)	Barcelona, Spain	Boston, USA	Budapest, Hungary (Bus)	Budapest, Hungary (Metro)	Glasgow, Scotland	Hamburg, Germany
9. How accurate is your service monitoring technology and how do you verify information gathered?								
Automatic Train Supervision	very accurate	to nearest second	-	-	-	-	-	detection in seconds, announcement in minutes
Automatic Vehicle Location	very accurate	-	-	98%, manual verif.	vehicle location within 50m and 30 sec	-	-	-
Other systemwide track or route based monitoring	-	-	-	-	-	80%, manual spot check verif.	very accurate	-
Manually by dispatching staff	-	-	-	accurate, estimated	manual spot checks	-	-	-
Manually by separate monitoring staff	-	to nearest minute	-	excellent	-	-	-	-
Camera surveillance	-	-	-	-	-	-	-	-
Other	-	-	-	-	-	-	-	in minutes
10. Is your agency considering installing new service monitoring technology?	no	yes	yes	yes	yes	no	no	no
11. If you answered yes to 10, please describe the type of technology and the manufacturer.	-	have current system provide service data	ATP, ATO: Bombardier	expand Siemens ITS	GPS vehicle location	-	-	-
12. What other data collection systems are integrated with service monitoring technology?	service quality	none, but ATS should provide car mileage	customer information systems	ITS	none	none	signal system monitoring	intermodal transfers, customer information displays

Service Monitoring Technology	Tokyo, Japan	Athens, Greece (Attiko)	Barcelona, Spain	Boston, USA	Budapest, Hungary (Bus)	Budapest, Hungary (Metro)	Glasgow, Scotland	Hamburg, Germany
13. What information does or will your technology provide for analysis?								
Current Technology								
Automatic Train Supervision	-	-	-	-	-	-	-	arrival/departure times
Automatic Vehicle Location	-	-	arrival times, continuous location	arrival times, car identification	arrival/ departure times	-	-	-
Other systemwide track or route based monitoring	-	-	arrival times, continuous location	-	-	vehicle & passenger loads, incidents	arrival times	-
Manually by dispatching staff	-	-	-		-	-	-	-
Manually by separate monitoring staff	-	-	-	car ID, loads on/off by stop, unit, & trip	-	-	-	-
Camera surveillance	-	-	-	none	-	-	-	-
Other	-	-	-	-	-	-	-	departure times
Future Technology								
Automatic Train Supervision	-	times, delays	-	-	-	-	-	technical & operational data; data link to maint. depts
Automatic Vehicle Location	-	-	arrival times, continuous location	arrival times, car identification	-	-	-	-
Other systemwide track or route based monitoring	-	-	arrival times, continuous location	-	-	-	-	-
Manually by dispatching staff	-	-	-	-	-	-	-	-
Manually by separate monitoring staff	-	-	-	-	-	-	-	-
Camera surveillance	-	-	-	-	-	-	-	-
Other	-	-	-	-	-	-	-	-

Service Monitoring Technology	Tokyo, Japan	Athens, Greece (Attiko)	Barcelona, Spain	Boston, USA	Budapest, Hungary (Bus)	Budapest, Hungary (Metro)	Glasgow, Scotland	Hamburg, Germany
14. How often do you gather information?								
Current Method								
Automatic Train Supervision	continuously	-	continuously	-	-	-	-	continuously
Automatic Vehicle Location	continuously	-	continuously	continuously	almost continuously; every 30 secs	-	-	-
Other systemwide track or route based monitoring	-	-	continuously	-	-	daily	continuously	-
Manually by dispatching staff	-		-	continuously	-	daily	-	-
Manually by separate monitoring staff	-	daily	-	as required	daily	-	-	-
Camera surveillance	-	-	-	-	-	-	-	-
Other	-	-	-	-	-	-	-	continuously
Future Method								
Automatic Train Supervision	-	-	continuously	-	-	-	-	continuously
Automatic Vehicle Location	-	-	continuously	-	-	-	-	-
Other systemwide track or route based monitoring	-	-	continuously	-	-	-	-	-
Manually by dispatching staff	-	-	-	-	-	-	-	-
Manually by separate monitoring staff	-	-	-	-	-	-	-	-
Camera surveillance	-	-	-	-	-	-	-	-
Other	-	-	-	-	-	-	-	continuously
15. At what level do you gather and analyze information?								
Automatic Train Supervision	system	-	-	-	-	-	-	gathered by station; analyzed by line, system
Automatic Vehicle Location	system	-	line, system	-	line	-	-	-
Other systemwide track or route based monitoring	-	-	line, system	-	-	line, division	route direction	-
Manually by dispatching staff	-	-	-	line, branch	-	line, division	-	-
Manually by separate monitoring staff	-	line	-	route	line	-	-	-
Camera surveillance	-	-	-	-	-	-	-	-
Other	-	-	-	-	-	-	-	station, system

Service Monitoring Technology	Tokyo, Japan	Athens, Greece (Attiko)	Barcelona, Spain	Boston, USA	Budapest, Hungary (Bus)	Budapest, Hungary (Metro)	Glasgow, Scotland	Hamburg, Germany
16. How long is data stored?								
	1 week-3 months	indefinitely	4 years	1 year	1 year	1 year	30 days	15 mos to 3+ yrs
17. What reports or analysis do you produce or do you expect to produce with the information gathered?								
Automatic Train Supervision	operational statistics	average lateness, headways	service quality	-	-	-	-	monthly OTP, quarterly service quality
Automatic Vehicle Location	operational statistics	-	service quality	-	OTP, schedule reliance, etc.	-	-	-
Other systemwide track or route based monitoring	-	-	service quality	-	-	schedule compliance, OTP, problems, etc.	headway, service quality	-
Manually by dispatching staff	-	-	-	-	schedule reliance, OTP, driver discipline	load capacity, accident causes	-	-
Manually by separate monitoring staff	-	average lateness for peak period, by line	-	-	comprehensive report every 3 months	-	-	-
Camera surveillance	-	-	-	-	-	-	-	-
Other	-	-	-	-	-	-	-	monthly station delay statistics; quarterly service quality reports

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Service Monitoring Technology	Tokyo, Japan	Athens, Greece (Attiko)	Barcelona, Spain	Boston, USA	Budapest, Hungary (Bus)	Budapest, Hungary (Metro)	Glasgow, Scotland	Hamburg, Germany
18. What problems or issues have you identified as a result of information gathered through service monitoring technology?*								
Automatic Train Supervision		-	-	-	-	-	-	number & location of delays; effects of low-speed service
Automatic Vehicle Location	-	-	-	none	irregularity, obstructions, discipline issues	-	-	-
Other systemwide track or route based monitoring	-	-	-	-	-	vehicle/ escalator load capacity	causes of service suspensions	-
Manually by dispatching staff	-	-	-	-	irregularity, discipline issues	escalator operation	-	-
Manually by separate monitoring staff	-	-	-	fiscal constraints	discipline issues, obstructions	-	-	-
Camera surveillance	-	-	-	-	-	-	-	-
Other	equipment maintenance, service issues	-	-	-	-	-	-	number & location of delays
*Several respondents reported problems with the technology itself. Please see individual responses.								
19. Has service monitoring technology helped to improve service provision?	yes	not yet	yes	yes	yes	yes	yes	yes
20. If you answered yes to 19, describe how you have used the technology to improve metro service?	preventive maintenance, efficient problem resolution	-	new timetables, number of trains, capacities, etc.	service gap resolution: turning trains, running express	traffic control efficiency, improved customer information	match schedules to demand	customer-focused view of service improvement, delay resolution	quick delay resolution, better planning of track work

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Service Monitoring Technology	Jersey City, USA (PATH)	Miami, USA	Milan, Italy	Montreal, Canada	Portland, USA	Prague, Czech Republic (Bus)	Prague, Czech Republic (Metro)	Rio de Janeiro, Brazil
4. How do you determine the reliability/punctuality of your vehicles?								
Automatic Train Supervision	no	limited	yes	-	yes	-	yes	yes
Automatic Vehicle Location	no	developing	yes	yes	yes	yes, trial use	yes	yes
Other systemwide track or route based monitoring	no	-	-	-	-	no	-	-
Manually by dispatching staff	yes	-	-	sometimes	-	yes	yes	-
Manually by separate monitoring staff	yes	limited	-	-	-	no	no	-
Camera surveillance	no	no	yes	-	-	yes, trial use	yes	-
Other	-	-	-	-	-	-	switch/signal monitors	-
5. How is technology used to disseminate collected data? (e.g., querying through an intranet, processing through a central analysis group)								
Automatic Train Supervision	N/A	mimic boards	-	-	planning dept; developing intranet	-	-	planning department
Automatic Vehicle Location	N/A	intranet	Telex & fax	intranet	planning dept; developing intranet	not yet available	-	planning department
Other systemwide track or route based monitoring	N/A	-	-	-	-	no	-	-
Manually by dispatching staff	manually entered into database	-	-	-	-	manually	manually	-
Manually by separate monitoring staff	control center & terminal supervisors	handheld computers	-	-	-	no	-	-
Camera surveillance	-	-	-	-	-	no	-	-
Other	-	-	-	-	-	-	-	-

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Service Monitoring Technology	Jersey City, USA (PATH)	Miami, USA	Milan, Italy	Montreal, Canada	Portland, USA	Prague, Czech Republic (Bus)	Prague, Czech Republic (Metro)	Rio de Janeiro, Brazil
6. What percentage of vehicles are monitored?								
Automatic Train Supervision	N/A	random sample	-	-	100%	-	100%	100%
Automatic Vehicle Location	N/A	100%	100%	10%	100%	20% trial operation	100%	100%
Other systemwide track or route based monitoring	N/A	-	-	-	-	-	-	-
Manually by dispatching staff	100%	-	-	as needed for specific purposes	-	60%	as required by operational situation	-
Manually by separate monitoring staff	100%	limited number	-	-	-	-	-	-
Camera surveillance	N/A	-	-	-	-	5% test terminal	100%	-
Other	-	-	-	-	-	-	100%	-
7. What percentage of stations or stops are monitored?								
Automatic Train Supervision	N/A	100%	-	-	33%	-	100%	100%
Automatic Vehicle Location	N/A	100%	-	100%	100%	by 200 buses at all stops on route	100%	26%
Other systemwide track or route based monitoring	N/A	-	-	-	-	-	-	-
Manually by dispatching staff	100%	-	-	as needed for specific purposes	-	13%	as required	-
Manually by separate monitoring staff	100%	few	-	-	-	no	-	-
Camera surveillance	N/A	-	100%	-	-	-	100%	-
Other	-	-	-	-	-	-	100%	-

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Service Monitoring Technology	Jersey City, USA (PATH)	Miami, USA	Milan, Italy	Montreal, Canada	Portland, USA	Prague, Czech Republic (Bus)	Prague, Czech Republic (Metro)	Rio de Janeiro, Brazil
8. Please describe the type, manufacturer and year of any service monitoring technology you use.								
Automatic Train Supervision	N/A	-	Automatic Train Operation	-	Union Switch and Signal SCADA system	-	UniControls PC network 1998	-
Automatic Vehicle Location	-	Harris	CRC, Thermic Plotter, 1990	Microtronix sensors; Init infrared	Orbital Sciences GPS-based dispatch system	GPS by APEX 1999	UniControls PC network 1998	-
Other systemwide track or route based monitoring	N/A	-	-	-	-	-	-	-
Manually by dispatching staff	N/A	-	-	-	-	-	UniControls PC network 1998	-
Manually by separate monitoring staff	N/A	-	-	-	-	-	-	-
Camera surveillance	-	-	B&W CCTV	-	-	ELBEX, ELVIJA, 1998	DV 380, ELVIJA, 1994	-
Other	display boards, 25+ yrs old	-	-	-	-	-	UniControls 1999	-

Appendix C: Service Monitoring Technology Survey Results

Service Monitoring Technology	Jersey City, USA (PATH)	Miami, USA	Milan, Italy	Montreal, Canada	Portland, USA	Prague, Czech Republic (Bus)	Prague, Czech Republic (Metro)	Rio de Janeiro, Brazil
9. How accurate is your service monitoring technology and how do you verify information gathered?								
Automatic Train Supervision	N/A	95%, statistical	-	-	very accurate-not officially verified	-	100%	-
Automatic Vehicle Location	N/A	developing	precise within 50m	95%, verif. by audits	very accurate-not officially verified	not yet available	100%	-
Other systemwide track or route based monitoring	N/A	-	-	-	-	-	-	-
Manually by dispatching staff	verify by manual comparison	-	-	-	-	-	depends on info provided by drivers	-
Manually by separate monitoring staff	N/A	reasonable	-	-	-	-	-	-
Camera surveillance	N/A	-	verify with slow motion	-	-	-	-	-
Other	-	-	-	-	-	-	100%	-
10. Is your agency considering installing new service monitoring technology?	yes	yes	yes--metro lines	yes	no	yes	no	-
11. If you answered yes to 10, please describe the type of technology and the manufacturer.	automatic train control, communication-based train tracking	-	expand ATS	Infrared: Init	-	GPS by APEX Prague	-	-
12. What other data collection systems are integrated with service monitoring technology?	passenger counting & fare collection	considering APC	surface: customer info, passenger counting, etc; metro: ATS	vehicle location: signposts & GPS	-	-	-	-

Appendix C: Service Monitoring Technology Survey Results

Service Monitoring Technology	Jersey City, USA (PATH)	Miami, USA	Milan, Italy	Montreal, Canada	Portland, USA	Prague, Czech Republic (Bus)	Prague, Czech Republic (Metro)	Rio de Janeiro, Brazil
13. What information does or will your technology provide for analysis?								
Current Technology								
Automatic Train Supervision	N/A	-	data on train operation; stopping, reversing, slowing	-	station leave times	-	-	arrival times at key stations
Automatic Vehicle Location	N/A	arrival/ departure times	metro: OTP, loads; bus: ridership, travel time	continuous location, OTP, platform/ vehicle loads	OTP, loads, vehicle ID, etc.	OTP	-	arrival times at key stations
Other systemwide track or route based monitoring	N/A	-	-	-	-	-	-	-
Manually by dispatching staff	N/A	-	-	-	-	arrival times	-	-
Manually by separate monitoring staff	N/A	-	-	-	-	-	-	-
Camera surveillance	-	-	vehicle loads	-	-	-	-	-
Other	-	-	-	-	-	-	switch and signal condition	-
Future Technology								
Automatic Train Supervision	times, headway	-	-	-	APC, loads	-	improve existing system	-
Automatic Vehicle Location	train identification	-	all data re: train location	times, continuous location, OTP, loads	-	develop system	improve existing system	-
Other systemwide track or route based monitoring	N/A	-	-	-	-	-	-	-
Manually by dispatching staff	continuous location	-	-	-	-	-	-	-
Manually by separate monitoring staff	N/A	-	-	-	-	-	-	-
Camera surveillance	-	-	-	-	-	-	improve existing system	-
Other	-	-	-	-	-	-	improve existing system	-

Service Monitoring Technology	Jersey City, USA (PATH)	Miami, USA	Milan, Italy	Montreal, Canada	Portland, USA	Prague, Czech Republic (Bus)	Prague, Czech Republic (Metro)	Rio de Janeiro, Brazil
14. How often do you gather information?								
Current Method								
Automatic Train Supervision	N/A	-	-	-	continuously	-	continuously	daily
Automatic Vehicle Location	N/A	-	continuously	continuously	continuously	continuously	continuously	daily
Other systemwide track or route based monitoring	N/A	-	-	-	-	-	-	-
Manually by dispatching staff	continuously	-	-	-	-	continuously	continuously	-
Manually by separate monitoring staff	continuously	-	-	-	-	-	-	-
Camera surveillance	-	-	continuously	-	-	continuously	as required	-
Other	-	-	-	-	-	-	continuously	-
Future Method								
Automatic Train Supervision	continuously	-	continuously	-		-	continuously	-
Automatic Vehicle Location	continuously	-	-	continuously		continuously	continuously	-
Other systemwide track or route based monitoring	none	-	-	-	-	-	-	-
Manually by dispatching staff	continuously	-	-	-	-	continuously	continuously	-
Manually by separate monitoring staff	continuously	-	-	-	-	-	-	-
Camera surveillance	-	-	continuously, manual capacity	-	-	-	as required	-
Other	-	-	-	-	-	-	continuously	-
15. At what level do you gather and analyze information?								
Automatic Train Supervision	N/A	route, run	line	-	line, route, system, time	-	line	line
Automatic Vehicle Location	N/A	-	line	stop, line, route, system, division, time of day	line, route, system, time	line; system	line	line
Other systemwide track or route based monitoring	N/A	-	-	-	-	-	-	-
Manually by dispatching staff	route, time	-	-	-	-	line	line	-
Manually by separate monitoring staff	route, time	-	-	-	-	-	-	-
Camera surveillance	-	-	line, station	-	-	-	system	-
Other	-	-	-	-	-	-	line	-

Service Monitoring Technology	Jersey City, USA (PATH)	Miami, USA	Milan, Italy	Montreal, Canada	Portland, USA	Prague, Czech Republic (Bus)	Prague, Czech Republic (Metro)	Rio de Janeiro, Brazil
16. How long is data stored?								
	-	developing	3 months to 5 years	-	archived	-	6 years	-
17. What reports or analysis do you produce or do you expect to produce with the information gathered?								
Automatic Train Supervision	N/A	-	-	-	OTP, service delivery, etc.	-	daily operations, monthly analysis	-
Automatic Vehicle Location	N/A	run times, run time deviations	service conformity index, OTP, passengers per line & time of day	OTP, loads per route-direction, for service level planning	OTP, service delivery, etc.	not yet available	daily operations, monthly analysis	-
Other systemwide track or route based monitoring	N/A	-	-	-	-	-	-	-
Manually by dispatching staff	OTP, customer service	-	-	-	-	statistical, managerial	operations	-
Manually by separate monitoring staff	OTP, customer service	-	-	-	-	-	-	-
Camera surveillance	-	-	security	-	-	-	operations	-
Other	-	-	-	-	-	-	operations, analysis	-

Appendix C: Service Monitoring Technology Survey Results

Service Monitoring Technology	Jersey City, USA (PATH)	Miami, USA	Milan, Italy	Montreal, Canada	Portland, USA	Prague, Czech Republic (Bus)	Prague, Czech Republic (Metro)	Rio de Janeiro, Brazil
18. What problems or issues have you identified as a result of information gathered through service monitoring technology?*								
Automatic Train Supervision	N/A	-	ATO stops speeding trains	-	-	-	OTP, delays	-
Automatic Vehicle Location	N/A	-	-	accuracy, reliability, integration with planning data	delays, headway, etc.	-	dwell times	-
Other systemwide track or route based monitoring	N/A	-	-	-	-	-	-	-
Manually by dispatching staff	N/A	-	-	-	-	-	passenger emergencies	-
Manually by separate monitoring staff	N/A	-	-	-	-	-	-	-
Camera surveillance	-	-	-	-	-	-	passenger frequency & behavior, safety	-
Other	-	-	-	-	-	-	timely identification of equipment failures	-
19. Has service monitoring technology helped to improve service provision?	N/A	yes	surface: yes; metro: no	yes	yes	-	yes	-
20. If you answered yes to 19, describe how you have used the technology to improve metro service?	-	improve run time accuracy	continuous service optimization	bus service planning	schedule adjustment, problem resolution, etc.	-	problem resolution, increased safety, better service	-

*Several respondents reported problems with the technology itself. Please see individual responses.

Appendix C: Service Monitoring Technology Survey Results

Service Monitoring Technology	San Francisco, USA (BART)	Singapore	South Africa	Sydney, Australia	Taipei, Taiwan	Toronto, Canada (Subway)	Toronto, Canada (Surface)
4. How do you determine the reliability/punctuality of your vehicles?							
Automatic Train Supervision	yes	yes	no	-	yes	yes	-
Automatic Vehicle Location	yes	yes, done by ATS	no	yes	-	yes	yes
Other systemwide track or route based monitoring	-	no	no	-	-	-	yes
Manually by dispatching staff	-	yes, done by ATS	no	-	-	-	-
Manually by separate monitoring staff	-	yes	yes	yes	-	-	yes
Camera surveillance	-	-	no	-	-	-	-
Other	-	-	-	-	-	-	-
5. How is technology used to disseminate collected data? (e.g., querying through an intranet, processing through a central analysis group)							
Automatic Train Supervision	central group, intranet, charts, reports	intranet, control center	-	-	intranet, manually, control room	central group	-
Automatic Vehicle Location	-	N/A	-	-	-	intranet	intranet, central group
Other systemwide track or route based monitoring	-	N/A	-	-	-	-	intranet, manually
Manually by dispatching staff	-	N/A	-	-	-	-	-
Manually by separate monitoring staff	-	intranet	-	central group, internet, reports	-	-	-
Camera surveillance	-	N/A	-	-	-	-	-
Other	-	-	-	-	-	-	-

Appendix C: Service Monitoring Technology Survey Results

Service Monitoring Technology	San Francisco, USA (BART)	Singapore	South Africa	Sydney, Australia	Taipei, Taiwan	Toronto, Canada (Subway)	Toronto, Canada (Surface)
6. What percentage of vehicles are monitored?							
Automatic Train Supervision	100%	all mainline stations	-	-	100%	100%	-
Automatic Vehicle Location	-	N/A	-	-	-	100%	100%
Other systemwide track or route based monitoring	-	N/A	-	-	-	-	77% buses; 82% streetcars
Manually by dispatching staff	-	N/A	80%	-	-	-	-
Manually by separate monitoring staff	-	-	80%	100% peak; 98% off-peak	-	-	-
Camera surveillance	-	N/A	-	-	-	-	-
Other	-	-	-	-	-	-	-
7. What percentage of stations or stops are monitored?							
Automatic Train Supervision	100%	100%	-	-	100%	20%, terminals & key stations	-
Automatic Vehicle Location	-	N/A	-	11% busiest	-	100%	-
Other systemwide track or route based monitoring	-	N/A	-	-	-	-	-
Manually by dispatching staff	-	N/A	-	-	-	-	-
Manually by separate monitoring staff	-	N/A	-	19%, CBD, terminals, key stations	-	-	-
Camera surveillance	-	N/A	-	-	-	-	-
Other	-	-	-	-	-	-	-

Appendix C: Service Monitoring Technology Survey Results

Service Monitoring Technology	San Francisco, USA (BART)	Singapore	South Africa	Sydney, Australia	Taipei, Taiwan	Toronto, Canada (Subway)	Toronto, Canada (Surface)
8. Please describe the type, manufacturer and year of any service monitoring technology you use.							
Automatic Train Supervision	ICS train control, 1995; various software	Westinghouse 1987	-	-	Alstom, 1995; Matra 1986	LSKS Signals, 1993	developed in-house, 1991
Automatic Vehicle Location	-	N/A	-	Train Location System, 2001	-	Wardrop, Inc., Advanced Railway Concepts, 1998	developed in-house, 1999
Other systemwide track or route based monitoring	-	N/A	-	-	-	-	-
Manually by dispatching staff	-	N/A	-	-	-	-	-
Manually by separate monitoring staff	-	N/A	-	manually since 1979	-	-	-
Camera surveillance	-	N/A	-	-	-	-	-
Other	-	-	-	-	-	-	-

Appendix C: Service Monitoring Technology Survey Results

Service Monitoring Technology	San Francisco, USA (BART)	Singapore	South Africa	Sydney, Australia	Taipei, Taiwan	Toronto, Canada (Subway)	Toronto, Canada (Surface)
9. How accurate is your service monitoring technology and how do you verify information gathered?							
Automatic Train Supervision	90-95%, verified by staff	deviation from 0-2 minutes, verify manually	-	-	nearly 100%, unverified	95%, manual	97%, verified by computer
Automatic Vehicle Location	-	N/A	-	-	-	inexact--only section occupancy	-
Other systemwide track or route based monitoring	-	N/A	-	-	-	-	-
Manually by dispatching staff	-	N/A	-	-	-	-	-
Manually by separate monitoring staff	-	N/A	-	peak 100%, verif. by computer; off-peak estimated 95-98%	-	-	-
Camera surveillance	-	N/A	-	-	-	-	-
Other	-	-	-	-	-	-	-
10. Is your agency considering installing new service monitoring technology?	yes	yes	-	yes	no	yes	yes
11. If you answered yes to 10, please describe the type of technology and the manufacturer.	PC-based AVL	upgrade Westinghouse PC-based ATS	-	Train Location System, transponders	-	Alstom Central Signal System train control	probably GPS-based AVL
12. What other data collection systems are integrated with service monitoring technology?	OTP, service quality, passenger environment, station equipment	N/A	-	train radio, train control	service quality, passenger counting, vehicle location	automated train dispatch	alarms, vehicle contact, service quality measures

Appendix C: Service Monitoring Technology Survey Results

Service Monitoring Technology	San Francisco, USA (BART)	Singapore	South Africa	Sydney, Australia	Taipei, Taiwan	Toronto, Canada (Subway)	Toronto, Canada (Surface)
13. What information does or will your technology provide for analysis?							
Current Technology							
Automatic Train Supervision	continuous location, equipment status, OTP	OTP, deviations	-	-	arrival/ departure times, OTP	arrival/ departure times	-
Automatic Vehicle Location	-	N/A	-	continuous location data	arrival/ departure times, OTP	none	vehicle location
Other systemwide track or route based monitoring	-	N/A	-	-	-	-	headway adherence
Manually by dispatching staff	vehicle loads	N/A	-	-	-	-	-
Manually by separate monitoring staff	-	N/A	-	arrival times, delays, causes	-	-	-
Camera surveillance	-	N/A	-	-	-	-	-
Other	-	-	-	-	-	-	-
Future Technology							
Automatic Train Supervision	equipment status	times, deviations	-	-	arrival/ departure times, OTP	OTP, arrival/ departure times, train ID	-
Automatic Vehicle Location	-	N/A	-	expand AVL location coverage	-	OTP, arrival/ departure times, train ID	GPS level accuracy
Other systemwide track or route based monitoring	-	N/A	-	-	-	-	same, but faster
Manually by dispatching staff	vehicle loads	N/A	-	-	-	-	-
Manually by separate monitoring staff	-	N/A	-	-	-	-	-
Camera surveillance	-	N/A	-	-	none	-	-
Other	-	-	-	-	-	-	-

Appendix C: Service Monitoring Technology Survey Results

Service Monitoring Technology	San Francisco, USA (BART)	Singapore	South Africa	Sydney, Australia	Taipei, Taiwan	Toronto, Canada (Subway)	Toronto, Canada (Surface)
14. How often do you gather information?							
Current Method							
Automatic Train Supervision	continuously	daily/ as required	-	-	High Capacity Transit (HCT):daily Medium Capacity Transit (MCT): continuously	daily	-
Automatic Vehicle Location	-	N/A	-	continuously	MCT: continuously	never	continuously, in real time
Other systemwide track or route based monitoring	-	N/A	-	-	-	-	weekly
Manually by dispatching staff	1, 2 times/ year	N/A	-	-	-	-	-
Manually by separate monitoring staff	-	N/A	-	twice a day	-	-	-
Camera surveillance	-	N/A	-	-	-	-	-
Other	-	-	-	-	-	-	-
Future Method							
Automatic Train Supervision	continuously	daily/ ad hoc	-	-	-	continuously	-
Automatic Vehicle Location	-	N/A	-	continuously	-	continuously	continuously
Other systemwide track or route based monitoring	-	N/A	-	-	-	-	continuously
Manually by dispatching staff	1, 2 times/ year	N/A	-	-	-	-	-
Manually by separate monitoring staff	-	N/A	-	continuously	-	-	-
Camera surveillance	-	N/A	-	-	-	-	-
Other	-	-	-	-	-	-	-
15. At what level do you gather and analyze information?							
Automatic Train Supervision	vehicle, time, sub-fleet, system	division	-	-	line	line	-
Automatic Vehicle Location	-	N/A	-	stations, nodes between stations	-	N/A	route
Other systemwide track or route based monitoring	-	N/A	-	-	-	-	route, division, system
Manually by dispatching staff	line	N/A	-	-	-	-	-
Manually by separate monitoring staff	-	division	-	line, train, station	-	-	-
Camera surveillance	-	N/A	-	-	-	-	-
Other	-	-	-	-	-	-	-

Service Monitoring Technology	San Francisco, USA (BART)	Singapore	South Africa	Sydney, Australia	Taipei, Taiwan	Toronto, Canada (Subway)	Toronto, Canada (Surface)
16. How long is data stored?	3 or more years	3 years	-	10 years	30 days	1 year	archived
17. What reports or analysis do you produce or do you expect to produce with the information gathered?							
Automatic Train Supervision	OTP, delay, causes	signaling performance	-	-	HCT: headway, speed, OTP	daily, weekly & monthly headway; OTP in future	-
Automatic Vehicle Location	-	N/A	-	headway, diversion	MCT: headway, speed, OTP	N/A	headways, vehicle performance, etc.
Other systemwide track or route based monitoring	-	N/A	-	-	-	-	headway adherence
Manually by dispatching staff	various	N/A	-	-	-	-	-
Manually by separate monitoring staff	-	N/A	-	OTP by line & train #, service disruptions, trends, etc.	-	-	-
Camera surveillance	-	N/A	-	-	-	-	-
Other	-	ad hoc/ signaling performance	-	-	-	-	-

Appendix C: Service Monitoring Technology Survey Results

Service Monitoring Technology	San Francisco, USA (BART)	Singapore	South Africa	Sydney, Australia	Taipei, Taiwan	Toronto, Canada (Subway)	Toronto, Canada (Surface)
18. What problems or issues have you identified as a result of information gathered through service monitoring technology?*							
Automatic Train Supervision	OTP, delays, equipment, passenger environment	equipment malfunctions, system design deficiencies	-	-	-	-	-
Automatic Vehicle Location	-	N/A	-	identify late trains	-	-	service gaps, bunching
Other systemwide track or route based monitoring	-	N/A	-	-	-	-	route-based: delays, schedule changes, etc.
Manually by dispatching staff	-	-	-	-	-	-	-
Manually by separate monitoring staff	-	-	-	delays, service performance, OTP percentage	-	-	-
Camera surveillance	-	-	-	-	-	-	-
Other	-	-	-	-	-	-	-
19. Has service monitoring technology helped to improve service provision?	yes	yes	-	yes	HCT: no, MCT: yes	yes	yes
20. If you answered yes to 19, describe how you have used the technology to improve metro service?	match service to demand, reduce car-hours	problem resolution, increased system availability	-	issue resolution, e.g., schedule changes, maintenance, training, etc.	match service to demand, properly equip & staff stations	problem resolution, performance measurement, schedule adjustment	schedule planning, contingency planning

*Several respondents reported problems with the technology itself. Please see individual responses.